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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 UF_6 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 ^{234}U, ^{235}U, and ^{238}U isotopes, contains 99.3% ^{238}U by weight [1]. Before use in a fission process, the concentration of the fissile ^{235}U 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% ^{235}U. Research reactors can require fuel enrichments up to 90%. Uranium-based atomic weapons require even higher enrichments, approaching 100% ^{235}U.

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 ^{238}U and ^{235}U 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 ^{238}U atoms are larger than the ^{235}U 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 ^{238}U –containing molecules to move closer to the outside of the rotor, where it is collected and sent to a depleted stream. The lighter ^{235}U-

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].

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:

1. 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 ^{235}U. 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 ^{235}U 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 UF_6 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 UF_6 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 UF_6, the primary source of neutrons comes from the (α, n) reaction of ^{19}F in the cylinder. The alpha particle comes from the spontaneous decay of ^{234}U. The concentration of ^{234}U is generally proportional to that of ^{235}U, so measurement of ^{235}U enrichment is possible through this technique, assuming a known ratio of ^{234}U to ^{235}U (thus if reprocessed uranium was being used, this technique would no longer be applicable without more research and understanding of the ratio of ^{234}U to ^{235}U in UF_6 process gas). Spontaneous decay of ^{238}U is also an important source of neutrons in UF_6. By counting the total neutrons from both the ^{234}U and the ^{238}U, 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.

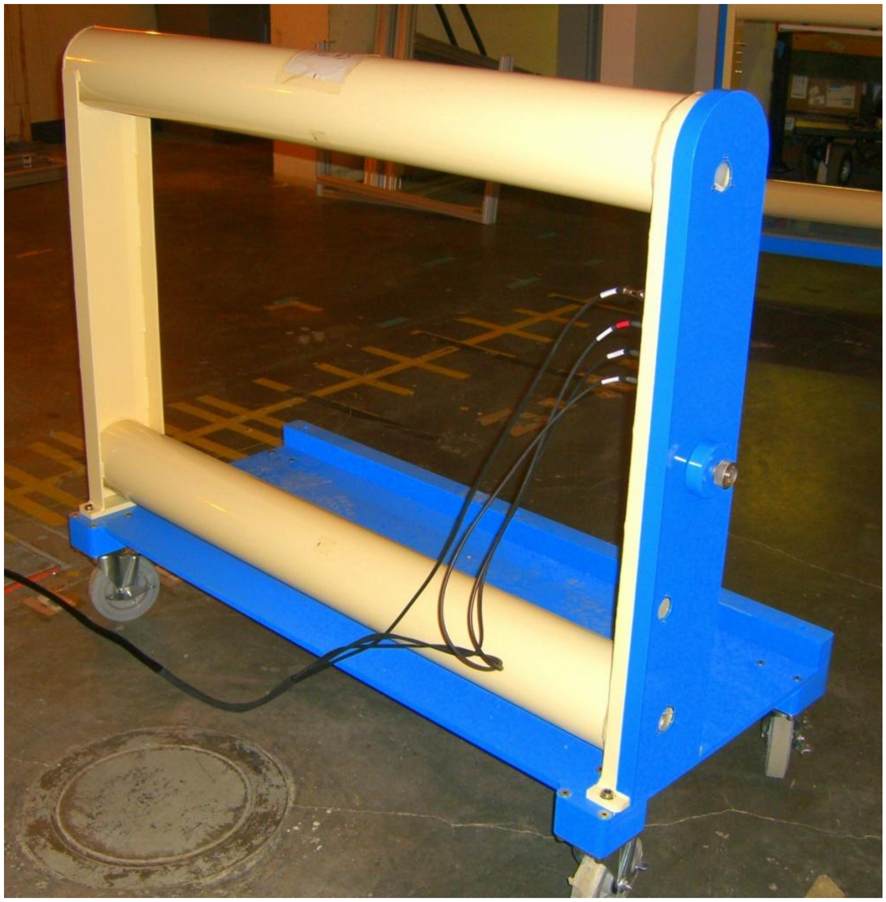

Figure 1: Mobile UCAS pod unit [16].

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 UF_6 gas in header pipes is based on NaI (Tl) detector measurement of the 186-keV gamma ray from ^{235}U and measurement of the UF_6 gas density through the attenuation of low energy radiation from a ^{109}Cd source. This methodology is currently used in the CEMO system. This proves difficult, however, since the ^{109}Cd 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 ^{109}Cd 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 UF_6 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.

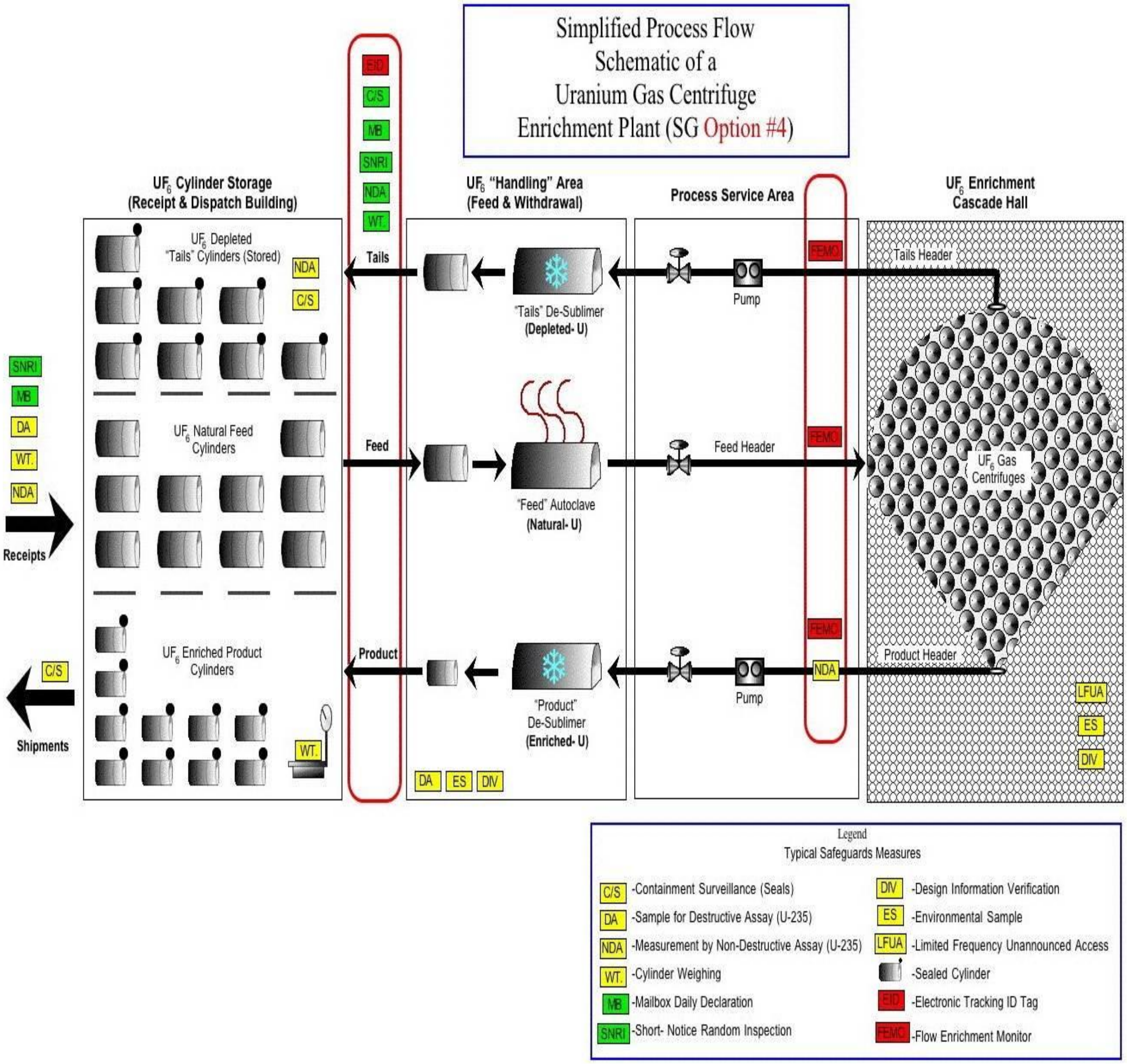

Figure 2: Simplified process flow schematic of a GCEP with Option D: AEM [18].

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 ^{235}U 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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690										
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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item 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
NaI 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 basis				**$ 20,625**		**$ 32,624**		**$ 105,971**		**$ 489,145**		**$ 503,445**
Equip. spares&installation =% of annual cost		**10%**		**$2,062**		**$3,262**		**$10,597**		**$48,915**		**$50,345**
Total Annual Equipment Costs				**$22,687**		**$35,886**		**$116,568**		**$538,060**		**$553,790**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**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 Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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 Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample 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 ^{3}He 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 ten-year 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		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 Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**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. Type												
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. Type												
Staff office costs for routine inspection				$ 27,826		$ 41,738		$ 55,651		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 527		$ 527		$ 527		$ 527		$ 527
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				**$ 38,366**		**$ 50,170**		**$ 71,988**		**$ 41,633**		**$ 41,633**
Total annual labor/staff/sampling costs				**$ 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$ reflecting accuracy			**$M**	**0.7**	**$M**	**0.6**	**$M**	**0.7**	**$M**	**0.8**	**$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 UF_6 into the centrifuge cascades(maximum temperature 140°C) and cold boxes which deposit (desublime) the UF_6 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 Sampling 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 Sampling 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 Sampling 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 Sampling 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	Option A	Option B	Option C	Option D	Option 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	Option A	Option B	Option C	Option D	Option 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 A	Option B	Option C	Option D	Option 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.

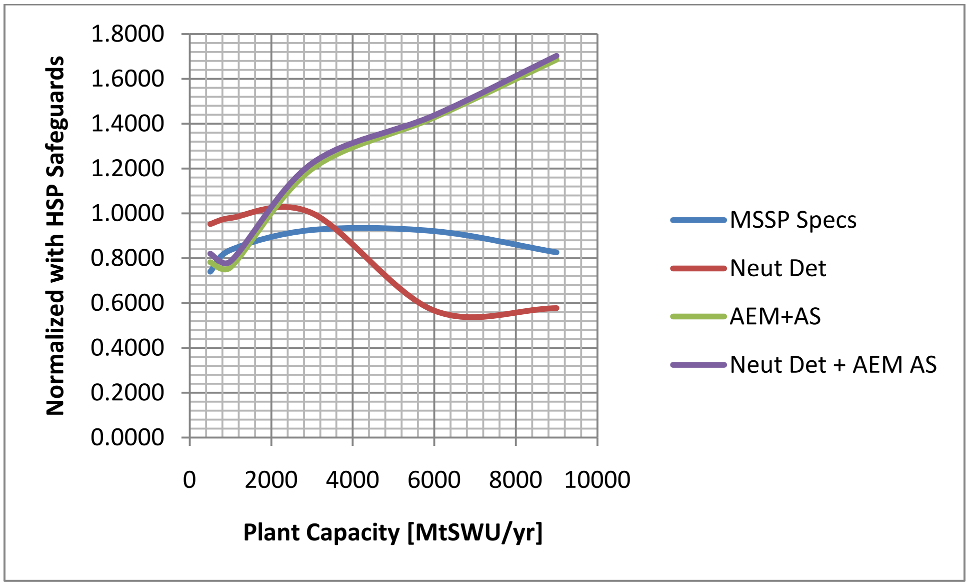

Figure 3: 153 Safeguards with NDA PD=50%, DA PD =50%

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.

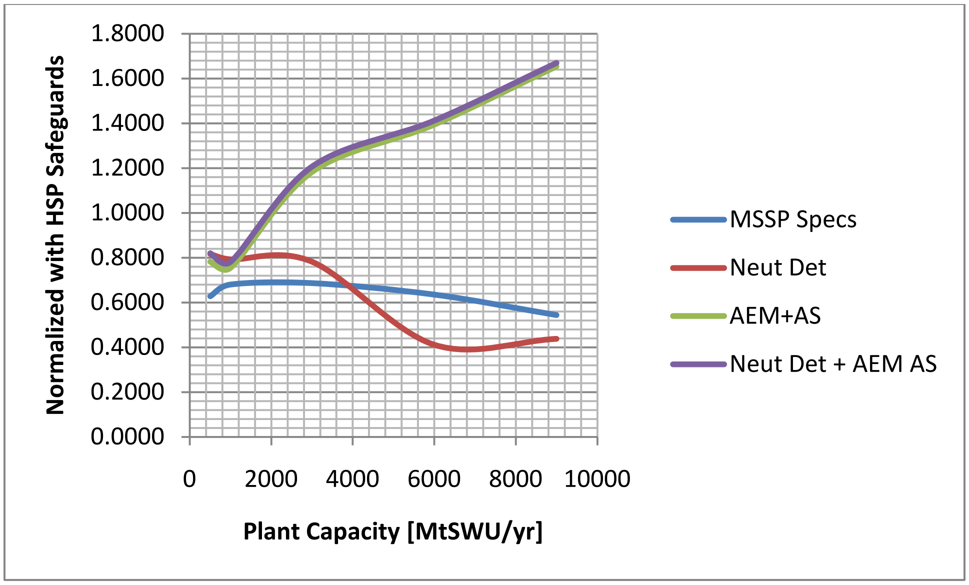

Figure 4: 153 Safeguards with NDA PD=50%, DA PD =10%

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 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for		Annual Cost/ item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item 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 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
NaI 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 system		$ 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 cabinet		$ 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		$ 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				$21,170		$32,374		$114,880		$184,112		$199,842
Annual equipment cost - repairs, trips, costs....as factor of equip.		% of Equip. Cost Factor										
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 Inspections		# of Inspections		# of Inspections		# of Inspections		# of Inspections
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 Regime		Cost/ Sample	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year
DA Sample - procedures /yr		$ 700	20	$ 14,000	28	$ 19,600	15	$ 10,500	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				$ 17,000		$ 22,600		$ 13,500		$ 5,100		$ 5,100

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

EXAMPLE GCEP of 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /ass	**115**	**115**										
Nom. Product cylinders/year	**59**	**59**										
Nom. Tails cylinders/year	**104**	**104**										
Cascade Halls	***8***	**8**										
Load cell monitors/assay un	***23***	**23**										
Assay units	***1***		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Inspection Staffing per Inspection 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
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				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)		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 - burdened				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. Type			**PDI**	Cost (USD)	**PDI**	Cost (USD)	**PDI**	Cost (USD)	**PDI**	Cost (USD)	**PDI**	Cost (USD)
Staff costs for routine inspection			33	$ 110,000	33	$ 110,000	33	$ 110,000	9	$ 30,000	9	$ 30,000
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			**71**	**$ 238,000**	**55**	**$ 174,000**	**55**	**$ 174,000**	**25**	**$ 82,000**	**25**	**$ 82,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 51,150		$ 51,150		$ 51,150		$ 13,950		$ 13,950
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				**$ 144,150**		**$ 69,750**		**$ 69,750**		**$ 32,550**		**$ 32,550**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 13,913		$ 20,869		$ 27,826		$ 9,486		$ 9,486
Staff office costs for suppl inspection				$ 527		$ 527		$ 527		$ 527		$ 527
Staff office costs for LFUA inspection				$ 2,108		$ -		$ -		$ -		$ -
Staff office costs for PIV inspection				$ 5,270		$ 5,270		$ 10,540		$ 14,756		$ 14,756
Total staff office costs				**$ 21,818**		**$ 26,666**		**$ 38,893**		**$ 24,769**		**$ 24,769**
Total annual labor/staff/sampling co				**$ 403,968**		**$ 270,416**		**$ 282,643**		**$ 139,319**		**$ 139,319**
Total Annual costs				**$ 444,254**		**$ 328,628**		**$ 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 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
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
NaI 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 system		$ 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 cabinet		$ 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		$ 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**		**$ 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 - repairs, trips, costs….as factor of equip.		**% of 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 Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample - procedures /yr		$ 700	20	$ 14,000	5	$ 3,500	3	$ 2,100	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				**$ 17,000**		**$ 6,500**		**$ 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 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /ass	115	115										
Nom. Product cylinders/year	59	59										
Nom. Tails cylinders/year	104	104.3333333										
Cascade Halls	8	8										
Load cell monitors/assay un	23	23										
Assay units	1		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Inspection Staffing per Inspection 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
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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**
Staff costs for routine inspection			27	$ 90,000	27	$ 90,000	24	$ 80,000	9	$ 30,000	9	$ 30,000
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			**61**	**$ 202,000**	**49**	**$ 154,000**	**46**	**$ 144,000**	**25**	**$ 82,000**	**25**	**$ 82,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 41,850		$ 41,850		$ 37,200		$ 13,950		$ 13,950
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				**$ 116,250**		**$ 60,450**		**$ 55,800**		**$ 32,550**		**$ 32,550**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 11,383		$ 17,075		$ 20,237		$ 9,486		$ 9,486
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				$ 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/sampling co				**$ 337,011**		**$ 237,322**		**$ 231,104**		**$ 139,319**		**$ 139,319**
Total Annual costs				**$ 377,298**		**$ 278,796**		**$ 362,234**		**$ 346,942**		**$ 364,245**
reflecting accuracy			**$M**	**0.4**	**$M**	**0.3**	**$M**	**0.4**	**$M**	**0.3**	**$M**	**0.4**

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 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		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 un	*23*	23										
Assay units	*1*		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for		Annual Cost/ item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item 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 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
NaI 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 system		$ 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 cabinet		$ 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		$ 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, trips, costs….as factor of equip.		**% of Equip. Cost Factor**										
Costs		**10.0%**		**$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 Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
No. routine inspections/yr				8		8		7		2		2
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 per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
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				**$ 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%

EXAMPLE GCEP of 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /ass	115	115										
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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Inspection Staffing per Inspection 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
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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**
Staff costs for routine inspection			24	$ 80,000	24	$ 80,000	21	$ 70,000	6	$ 20,000	6	$ 20,000
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			**58**	**$ 192,000**	**46**	**$ 144,000**	**43**	**$ 134,000**	**22**	**$ 72,000**	**22**	**$ 72,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 37,200		$ 37,200		$ 32,550		$ 9,300		$ 9,300
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				**$ 111,600**		**$ 55,800**		**$ 51,150**		**$ 27,900**		**$ 27,900**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 10,118		$ 15,178		$ 17,707		$ 6,324		$ 6,324
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				$ 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/sampling co				**$ 321,096**		**$ 220,775**		**$ 213,924**		**$ 121,507**		**$ 121,507**
Total Annual costs				**$ 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 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	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 uni	*23*	23										
Assay units	*1*		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
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 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
NaI 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 system		$ 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 cabinet		$ 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		$ 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**		**$114,573**		**$184,112**		**$199,842**
Annual equipment cost - repairs, trips, costs….as factor of equip.		**% of 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 Inspections**
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 per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample - procedures /yr		$ 700	7	$ 4,900	5	$ 3,500	3	$ 2,100	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				**$ 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%

EXAMPLE GCEP of 500 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /ass	115	115										
Nom. Product cylinders/year	59	59										
Nom. Tails cylinders/year	104	104.3333333										
Cascade Halls	8	8										
Load cell monitors/assay un	23	23										
Assay units	1		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Inspection Staffing per Inspection 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
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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**
Staff costs for routine inspection			21	$ 70,000	21	$ 70,000	18	$ 60,000	9	$ 30,000	9	$ 30,000
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			**55**	**$ 182,000**	**43**	**$ 134,000**	**40**	**$ 124,000**	**25**	**$ 82,000**	**25**	**$ 82,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 32,550		$ 32,550		$ 27,900		$ 13,950		$ 13,950
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				**$ 106,950**		**$ 51,150**		**$ 46,500**		**$ 32,550**		**$ 32,550**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 8,854		$ 13,280		$ 15,178		$ 9,486		$ 9,486
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				$ 5,270		$ 5,270		$ 10,540		$ 14,756		$ 14,756
Total staff office costs				**$ 16,232**		**$ 19,077**		**$ 26,245**		**$ 24,769**		**$ 24,769**
Total annual labor/staff/sampling co				**$ 305,182**		**$ 204,227**		**$ 196,745**		**$ 139,319**		**$ 139,319**
Total Annual costs				**$ 336,012**		**$ 245,701**		**$ 327,875**		**$ 346,942**		**$ 364,245**
reflecting accuracy			**$M**	**0.3**	**$M**	**0.2**	**$M**	**0.3**	**$M**	**0.3**	**$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_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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL		Option A		Option B		Option C		Option D		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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
DA Sample Bottles		$ 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
NaI 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	555.3333	$ 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 basis				**$ 19,710**		**$ 30,067**		**$ 104,716**		**$ 231,744**		**$ 246,044**
Equip. spares&installation =%of annual 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, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,168.1**		**$3,307.3**		**$11,518.7**		**$25,491.8**		**$27,064.8**
Total Annual Equipment Costs				**$ 23,849**		**$ 36,380**		**$ 126,706**		**$ 280,410**		**$ 297,713**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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 Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample 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				**$ 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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option 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	16										
Load cell monitors/assay unit	23	46										
Assay units	2		Trad/Int Sgds		MSSP SPECS		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				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				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)		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 - burdened				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. Type			PDI	Cost (USD)	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			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**	**34**	**$ 112,000**	**34**	**$ 112,000**
Inspector Travel Costs by Insp. Type												
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				$ 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. Type												
Staff office costs for routine inspection				$ 27,826		$ 41,738		$ 55,651		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 527		$ 527		$ 527		$ 527		$ 527
Staff office costs for LFUA inspection				$ 2,108		$ -		$ -		$ -		$ -
Staff office costs for PIV inspection				$ 5,270		$ 5,270		$ 10,540		$ 14,756		$ 14,756
Total staff office costs				**$ 35,731**		**$ 47,535**		**$ 66,718**		**$ 34,255**		**$ 34,255**
Total annual labor/staff/sampling costs				**$ 579,031**		**$ 452,435**		**$ 471,618**		**$ 192,755**		**$ 192,755**
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%

EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	230										
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	2		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
DA Sample Bottles		$ 16	60	$ 930	15	$ 233	9	$ 140	5	$ 78	5	$ 78
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
NaI 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	555.3333	$ 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 basis				**$ 19,710**		**$ 29,013**		**$ 104,220**		**$ 231,651**		**$ 245,951**
Equip. spares&installation =% of annual cost		**10%**		**$1,971**		**$2,901**		**$10,422**		**$23,165**		**$24,595**
Total Annual Equipment Costs				**$21,681**		**$31,914**		**$114,641**		**$254,816**		**$270,546**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$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**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/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%

EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option 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*	16										
Load cell monitors/assay unit	*23*	46										
Assay units	*2*		Trad/Int Sgds		MSSP SPECS		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				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				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)		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 - burdened				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. Type			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. Type												
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				$ 9,300		$ 9,300		$ 9,300		$ 9,300		$ 9,300
Total travel cost				**$ 158,100**		**$ 102,300**		**$ 93,000**		**$ 46,500**		**$ 46,500**
Inspector Office Costs by Insp. Type												
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				$ 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**		**$ 51,541**		**$ 34,255**		**$ 34,255**
Total annual labor/staff/sampling 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			**$M**	**0.5**	**$M**	**0.4**	**$M**	**0.5**	**$M**	**0.5**	**$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%

EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	230										
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	2		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total 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 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
NaI 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 basis				**$ 19,106**		**$ 29,230**		**$ 104,313**		**$ 231,651**		**$ 245,951**
Equip. spares&installation =%of annual cost		**10%**		**$1,911**		**$2,923**		**$10,431**		**$23,165**		**$24,595**
Total Annual Equipment Costs				**$21,016**		**$32,152**		**$114,744**		**$254,816**		**$270,546**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,101.6**		**$3,215.2**		**$11,474.4**		**$25,481.6**		**$27,054.6**
Total Annual Equipment Costs				**$ 23,118**		**$ 35,368**		**$ 126,218**		**$ 280,298**		**$ 297,601**
Inspections Needed per Option Regime				**# 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
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/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				**$ 12,800**		**$ 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%

EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	230										
Nom. Product cylinders/year	59	118										
Nom. Tails cylinders/year	104	209										
Cascade Halls	8	16										
Load cell monitors/assay unit	23	46										
Assay units	2		Trad/Int Sgds		MSSP SPECS		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				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				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)**		**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 - burdened				**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. Type			**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	$ 56,000	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. Type												
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				$ 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. Type												
Staff office costs for routine inspection				$ 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				$ 5,270		$ 5,270		$ 10,540		$ 14,756		$ 14,756
Total staff office costs				**$ 27,615**		**$ 36,152**		**$ 46,481**		**$ 34,255**		**$ 34,255**
Total annual labor/staff/sampling costs				**$ 448,415**		**$ 353,152**		**$ 334,181**		**$ 192,755**		**$ 192,755**
Total Annual costs				**$ 484,332**		**$ 404,820**		**$ 470,400**		**$ 478,153**		**$ 495,456**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**0.5**	**$M**	**0.4**	**$M**	**0.5**	**$M**	**0.5**	**$M**	**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%

EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total 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 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
NaI 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	555.3333	$ 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 basis				**$ 19,106**		**$ 29,013**		**$ 104,220**		**$ 231,651**		**$ 245,951**
Equip. spares&installation =% of annual 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, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,101.6**		**$3,191.4**		**$11,464.1**		**$25,481.6**		**$27,054.6**
Total Annual Equipment Costs				**$ 23,118**		**$ 35,105**		**$ 126,106**		**$ 280,298**		**$ 297,601**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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 per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample - procedures /yr		$ 700	14	$ 9,800	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				**$ 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%

EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option 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	16										
Load cell monitors/assay unit	23	46										
Assay units	2		Trad/Int Sgds		MSSP SPECS		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				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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (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
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			**76**	**$ 252,000**	**64**	**$ 204,000**	**58**	**$ 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				$ 527		$ 527		$ 527		$ 527		$ 527
Staff office costs for LFUA inspection				$ 1,581		$ -		$ -		$ -		$ -
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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690										
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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item 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
NaI 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 basis				**$ 20,625**		**$ 32,624**		**$ 105,971**		**$ 489,145**		**$ 503,445**
Equip. spares&installation =% of annual cost		**10%**		**$2,062**		**$3,262**		**$10,597**		**$48,915**		**$50,345**
Total Annual Equipment Costs				**$22,687**		**$35,886**		**$116,568**		**$538,060**		**$553,790**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		% of Equip. Cost Factor										
Est. Annual Equipment Upkeep Costs		**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 Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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 Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample 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**

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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		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 Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**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. Type												
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. Type												
Staff office costs for routine inspection				$ 27,826		$ 41,738		$ 55,651		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 527		$ 527		$ 527		$ 527		$ 527
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				**$ 38,366**		**$ 50,170**		**$ 71,988**		**$ 41,633**		**$ 41,633**
Total annual labor/staff/sampling costs				**$ 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$ reflecting accuracy			**$M**	**0.7**	**$M**	**0.6**	**$M**	**0.7**	**$M**	**0.8**	**$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%

EXAMPLE GCEP of 3000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690										
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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
DA Sample Bottles		$ 16	119	$ 1,845	41	$ 636	20	$ 310	8	$ 124	8	$ 124
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
NaI 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 basis				**$ 20,625**		**$ 29,416**		**$ 104,390**		**$ 488,804**		**$ 503,104**
Equip. spares&installation =% of annual cost		**10%**		**$2,062**		**$2,942**		**$10,439**		**$48,880**		**$50,310**
Total Annual Equipment Costs				**$22,687**		**$32,357**		**$114,829**		**$537,684**		**$553,414**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,268.7**		**$3,235.7**		**$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 Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample - procedures /yr		$ 700	79	$ 55,300	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				**$ 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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		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 Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**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			30	$ 84,000	30	$ 84,000	30	$ 84,000	21	$ 66,000	21	$ 66,000
Total Inspector Labor Cost			**98**	**$ 320,000**	**86**	**$ 272,000**	**80**	**$ 252,000**	**41**	**$ 134,000**	**41**	**$ 134,000**
Inspector Travel Costs by Insp. Type												
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				$ 13,950		$ 13,950		$ 13,950		$ 13,950		$ 13,950
Total travel cost				**$ 162,750**		**$ 106,950**		**$ 97,650**		**$ 51,150**		**$ 51,150**
Inspector Office Costs by Insp. Type												
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				$ 1,581		$ -		$ -		$ -		$ -
Staff office costs for PIV inspection				$ 7,905		$ 7,905		$ 15,810		$ 22,134		$ 22,134
Total staff office costs				**$ 32,779**		**$ 42,582**		**$ 56,811**		**$ 41,633**		**$ 41,633**
Total annual labor/staff/sampling costs				**$ 515,529**		**$ 421,532**		**$ 406,461**		**$ 226,783**		**$ 226,783**
Total Annual costs				**$ 598,785**		**$ 479,024**		**$ 544,873**		**$ 824,736**		**$ 842,039**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**0.6**	**$M**	**0.5**	**$M**	**0.5**	**$M**	**0.8**	**$M**	**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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690										
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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		Annual Cost/ item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost
DA Sample Bottles		$ 16	60	$ 930	80	$ 1,240	41	$ 636	12	$ 186	12	$ 186
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
NaI 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 basis				$ 19,710		$ 30,020		$ 104,716		$ 488,866		$ 503,166
Equip. spares&installation =%of annual 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, trips, costs....as factor of equip. cost		% of Equip. Cost Factor										
Est. Annual Equipment Upkeep Costs		10.0%		$2,168.1		$3,302.2		$11,518.7		$53,775.3		$55,348.3
Total Annual Equipment Costs				$ 23,849		$ 36,324		$ 126,706		$ 591,528		$ 608,831
Inspections Needed per Option Regime				# 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
Annual Sample Procedure Costs per Option Regime		Cost/ Sample	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		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 Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**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			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. Type												
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				$ 55,800		$ -		$ -		$ -		$ -
Travel costs for PIV inspection				$ 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. Type												
Staff office costs for routine inspection				$ 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 costs				**$ 483,700**		**$ 388,437**		**$ 372,101**		**$ 226,783**		**$ 226,783**
Total Annual costs				**$ 538,549**		**$ 464,861**		**$ 520,707**		**$ 826,911**		**$ 844,214**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**0.5**	**$M**	**0.5**	**$M**	**0.5**	**$M**	**0.8**	**$M**	**0.8**

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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690										
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 Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
DA Sample Bottles		$ 16	60	$ 930	41	$ 636	20	$ 310	8	$ 124	8	$ 124
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
NaI 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 basis				**$ 19,710**		**$ 29,416**		**$ 104,390**		**$ 488,804**		**$ 503,104**
Equip. spares&installation =% of annual cost		**10%**		**$1,971**		**$2,942**		**$10,439**		**$48,880**		**$50,310**
Total Annual Equipment Costs				**$21,681**		**$32,357**		**$114,829**		**$537,684**		**$553,414**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		% of Equip. Cost Factor										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,168.1**		**$3,235.7**		**$11,482.9**		**$53,768.4**		**$55,341.4**
Total Annual Equipment Costs				**$ 23,849**		**$ 35,593**		**$ 126,312**		**$ 591,453**		**$ 608,756**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
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 per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**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_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%

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option 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										
Cascade Halls	*8*	96										
Load cell monitors/assay unit	*23*	276										
Assay units	*12*		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
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
Load cell monitors		$ 500	0	$ -	0	$ -	0	$ -	276	$ 138,000	276	$ 138,000
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		$ [illegible]	0	$ -	0	$ -	0	$ -	162	$ 3,240	162	$ 3,240
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 basis				**$ 24,314**		**$ 36,437**		**$ 107,847**		**$ 875,255**		**$ 889,555**
Equip. spares&installation =% of annual cost		**10%**		**$2,431**		**$3,644**		**$10,785**		**$87,525**		**$88,955**
Total Annual Equipment Costs				**$26,745**		**$40,081**		**$118,631**		**$962,780**		**$978,510**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,674.5**		**$4,008.1**		**$11,863.1**		**$96,278.0**		**$97,851.0**
Total Annual Equipment Costs				**$ 29,419**		**$ 44,089**		**$ 130,494**		**$ 1,059,058**		**$ 1,076,361**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
No. routine inspections/yr				11		11		4		3		3
No. supplemental inspections/yr				7		12		3		3		2
No. Add'l LFUA inspections/yr				12		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample procedures/yr		$ 700	238	$ 166,600	329	$ 230,300	162	$ 113,400	39	$ 27,300	39	$ 27,300
ES Samples/yr		$ 500	6	$ 3,000	6	$ 3,000	6	$ 3,000	6	$ 3,000	6	$ 3,000
TOTAL Sample Costs/yr				**$ 169,600**		**$ 233,300**		**$ 116,400**		**$ 30,300**		**$ 30,300**

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

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		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*											
Inspection Staffing per Inspection 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				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		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/Analysis)				**Length (Days)**		**Length (Days)**		**Length (Days)**		**Length (Days)**		**Length (Days)**
Office days/routine 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 (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			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (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			24	$ 96,000	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			**127**	**$ 428,000**	**108**	**$ 352,000**	**57**	**$ 176,000**	**42**	**$ 138,000**	**41**	**$ 134,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 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=10%

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option 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										
Cascade Halls	8	96										
Load cell monitors/assay unit	23	276										
Assay units	12		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		Annual Cost/ item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost
DA Sample Bottles		$ 16	357	$ 5,534	77	$ 1,194	38	$ 589	12	$ 186	12	$ 186
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
NaI 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 basis				$ 24,314		$ 29,974		$ 104,669		$ 874,526		$ 888,826
Equip. spares&installation =% of annual cost		10%		$2,431		$2,997		$10,467		$87,453		$88,883
Total Annual Equipment Costs				$26,745		$32,971		$115,136		$961,979		$977,709
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		% of Equip. Cost Factor										
Est. Annual Equipment Upkeep Costs		10.0%		$2,674.5		$3,297.1		$11,513.6		$96,197.9		$97,770.9
Total Annual Equipment Costs				$ 29,419		$ 36,268		$ 126,649		$ 1,058,176		$ 1,075,479
Inspections Needed per Option Regime				# of Inspections		# of Inspections		# of Inspections		# of Inspections		# of Inspections
No. routine inspections/yr				11		11		3		3		3
No. supplemental inspections/yr				7		5		2		2		2
No. Addl LFUA inspections/yr				12		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		Cost/ Sample	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year
DA Sample - procedures /yr		$ 700	238	$ 166,600	51	$ 35,700	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				$ 169,600		$ 38,700		$ 20,500		$ 8,600		$ 8,600

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

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		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 Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**
Staff costs for routine inspection			66	$ 220,000	66	$ 220,000	18	$ 60,000	18	$ 60,000	18	$ 60,000
Staff costs for suppl inspection			7	$ 28,000	5	$ 20,000	2	$ 8,000	2	$ 8,000	2	$ 8,000
Staff costs for LFUA inspection			24	$ 96,000	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			**127**	**$ 428,000**	**101**	**$ 324,000**	**50**	**$ 152,000**	**41**	**$ 134,000**	**41**	**$ 134,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 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				**$ 260,400**		**$ 139,500**		**$ 51,150**		**$ 51,150**		**$ 51,150**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 27,826		$ 41,738		$ 15,178		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 1,845		$ 1,318		$ 527		$ 527		$ 527
Staff office costs for LFUA inspection				$ 3,162		$ -		$ -		$ -		$ -
Staff office costs for PIV inspection				$ 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 costs				**$ 729,137**		**$ 514,461**		**$ 234,665**		**$ 226,783**		**$ 226,783**
Total Annual costs				**$ 928,156**		**$ 589,429**		**$ 381,814**		**$ 1,293,559**		**$ 1,310,862**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**0.9**	**$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%

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option 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										
Cascade Halls	8	96										
Load cell monitors/assay unit	23	276										
Assay units	12		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		Annual Cost/ item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item 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
NaI 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 basis				$ 20,578		$ 31,245		$ 105,289		$ 874,650		$ 888,950
Equip. spares&installation =%of annual cost		10%		$2,058		$3,124		$10,529		$87,465		$88,895
Total Annual Equipment Costs				$22,636		$34,369		$115,818		$962,115		$977,845
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		% of Equip. Cost Factor										
Est. Annual Equipment Upkeep Costs		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 Regime				# of Inspections		# of Inspections		# of Inspections		# of Inspections		# of Inspections
No. routine inspections/yr				11		13		3		3		3
No. supplemental inspections/yr				7		5		2		2		2
No. Addl LFUA inspections/yr				12		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		Cost/ Sample	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample 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%

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		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 Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**
Staff costs for routine inspection			66	$ 220,000	78	$ 260,000	18	$ 60,000	18	$ 60,000	18	$ 60,000
Staff costs for suppl inspection			7	$ 28,000	5	$ 20,000	2	$ 8,000	2	$ 8,000	2	$ 8,000
Staff costs for LFUA inspection			24	$ 96,000	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			**127**	**$ 428,000**	**113**	**$ 364,000**	**50**	**$ 152,000**	**41**	**$ 134,000**	**41**	**$ 134,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 102,300		$ 120,900		$ 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				**$ 260,400**		**$ 158,100**		**$ 51,150**		**$ 51,150**		**$ 51,150**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 27,826		$ 49,327		$ 15,178		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 1,845		$ 1,318		$ 527		$ 527		$ 527
Staff office costs for LFUA inspection				$ 3,162		$ -		$ -		$ -		$ -
Staff office costs for PIV inspection				$ 7,905		$ 7,905		$ 15,810		$ 22,134		$ 22,134
Total staff office costs				**$ 40,737**		**$ 58,550**		**$ 31,515**		**$ 41,633**		**$ 41,633**
Total annual labor/staff/sampling costs				**$ 729,137**		**$ 580,650**		**$ 234,665**		**$ 226,783**		**$ 226,783**
Total Annual costs				**$ 810,936**		**$ 695,656**		**$ 401,464**		**$ 1,297,210**		**$ 1,314,513**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**0.8**	**$M**	**0.7**	**$M**	**0.4**	**$M**	**1.3**	**$M**	**1.3**

Table 41: Hardware 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	Option A		Option 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										
Cascade Halls	*8*	96										
Load cell monitors/assay unit	*23*	276										
Assay units	*12*		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item 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 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
NaI 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 basis				**$ 18,920**		**$ 29,090**		**$ 104,669**		**$ 874,526**		**$ 888,826**
Equip. spares&installation =% of annual cost		**10%**		**$1,892**		**$2,909**		**$10,467**		**$87,453**		**$88,883**
Total Annual Equipment Costs				**$20,811**		**$31,999**		**$115,136**		**$961,979**		**$977,709**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
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 Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
No. routine inspections/yr				8		8		3		3		3
No. supplemental inspections/yr				7		5		2		2		2
No. Addl LFUA inspections/yr				12		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample 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	Option A		Option B		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 Sgds		MSSP SPECS		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				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)		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				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)		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 - burdened				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. Type			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	18	$ 60,000	18	$ 60,000	18	$ 60,000
Staff costs for suppl inspection			7	$ 28,000	5	$ 20,000	2	$ 8,000	2	$ 8,000	2	$ 8,000
Staff costs for LFUA inspection			24	$ 96,000	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			**109**	**$ 368,000**	**83**	**$ 264,000**	**50**	**$ 152,000**	**41**	**$ 134,000**	**41**	**$ 134,000**
Inspector Travel Costs by Insp. Type												
Travel costs for routine inspection				$ 74,400		$ 74,400		$ 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				**$ 232,500**		**$ 111,600**		**$ 51,150**		**$ 51,150**		**$ 51,150**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 20,237		$ 30,355		$ 15,178		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 1,845		$ 1,318		$ 527		$ 527		$ 527
Staff office costs for LFUA inspection				$ 3,162		$ -		$ -		$ -		$ -
Staff office costs for PIV inspection				$ 7,905		$ 7,905		$ 15,810		$ 22,134		$ 22,134
Total staff office costs				**$ 33,148**		**$ 39,578**		**$ 31,515**		**$ 41,633**		**$ 41,633**
Total annual labor/staff/sampling costs				**$ 633,648**		**$ 415,178**		**$ 234,665**		**$ 226,783**		**$ 226,783**
Total Annual costs				**$ 663,741**		**$ 462,477**		**$ 381,814**		**$ 1,293,559**		**$ 1,310,862**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**0.7**	**$M**	**0.5**	**$M**	**0.4**	**$M**	**1.3**	**$M**	**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_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%

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	2070										
Nom. Product cylinders/year	58	1050										
Nom. Tails cylinders/year	104	1878										
Cascade Halls	8	144										
Load cell monitors/assay unit	23	414										
Assay units	18		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item 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 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
NaI 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	$ -	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**		**$ 40,250**		**$ 109,707**		**$ 1,261,349**		**$ 1,275,649**
Equip. spares&installation =% of annual cost		**10%**		**$2,706**		**$4,025**		**$10,971**		**$126,135**		**$127,565**
Total Annual Equipment Costs				**$29,763**		**$44,275**		**$120,677**		**$1,387,483**		**$1,403,213**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% 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 Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# 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		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/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				**$ 252,200**		**$ 348,100**		**$ 172,400**		**$ 43,600**		**$ 43,600**

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 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option 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	*18*		Trad/Int Sgds		MSSP SPECS			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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**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	$ 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												
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 costs				**$ 786,202**		**$ 487,720**		**$ 312,297**		**$ 235,697**		**$ 235,697**
Total Annual costs				**$ 1,071,140**		**$ 884,523**		**$ 617,441**		**$ 1,805,528**		**$ 1,822,831**
Total Annual costs in 1M$ reflecting accuracy			**$M**	**1.1**	**$M**	**0.9**	**$M**	**0.6**	**$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%

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	2070										
Nom. Product cylinders/year	58	1050										
Nom. Tails cylinders/year	104	1878										
Cascade Halls	8	144										
Load cell monitors/assay unit	23	414										
Assay units	18		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		Annual Cost/ item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total 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 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
NaI 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	$ -	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 annual cost		**10%**		**$2,706**		**$3,058**		**$10,496**		**$126,026**		**$127,456**
Total Annual Equipment Costs				**$29,763**		**$33,636**		**$115,460**		**$1,386,290**		**$1,402,020**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% 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				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# 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		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/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				**$ 252,200**		**$ 56,900**		**$ 29,600**		**$ 10,700**		**$ 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%

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option 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 Sgds		MSSP SPECS		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				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)		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				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)		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 - burdened				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. Type			**PDI**	Cost (USD)	**PDI**	Cost (USD)	**PDI**	Cost (USD)	**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	$ 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												
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 costs				**$ 786,202**		**$ 487,720**		**$ 312,297**		**$ 235,697**		**$ 235,697**
Total Annual costs				**$ 1,071,140**		**$ 581,620**		**$ 468,902**		**$ 1,771,315**		**$ 1,788,618**
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%

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	2070										
Nom. Product cylinders/year	58	1050										
Nom. Tails cylinders/year	104	1878										
Cascade Halls	8	144										
Load cell monitors/assay unit	23	414										
Assay units	18		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
DA Sample Bottles		$ 16	173	$ 2,682	239	$ 3,705	119	$ 1,845	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
NaI 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	$ -	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				**$ 21,462**		**$ 32,485**		**$ 105,925**		**$ 1,260,465**		**$ 1,274,765**
Equip. spares&installation =%of annual cost		**10%**		**$2,146**		**$3,248**		**$10,592**		**$126,047**		**$127,477**
Total Annual Equipment Costs				**$23,608**		**$35,733**		**$116,517**		**$1,386,512**		**$1,402,242**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,360.8**		**$3,573.3**		**$11,651.7**		**$138,651.2**		**$140,224.2**
Total Annual Equipment Costs				**$ 25,968**		**$ 39,306**		**$ 128,169**		**$ 1,525,163**		**$ 1,542,466**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# 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		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample - procedures /yr		$ 700	115	$ 80,500	159	$ 111,300	79	$ 55,300	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				**$ 83,500**		**$ 114,300**		**$ 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%

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option 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	*18*		Trad/Int Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**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	$ 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												
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 costs				**$ 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 costs in 1M$ reflecting accuracy			**$M**	**0.9**	**$M**	**0.6**	**$M**	**0.5**	**$M**	**1.8**	**$M**	**1.8**

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

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	2070										
Nom. Product cylinders/year	58	1050										
Nom. Tails cylinders/year	104	1878										
Cascade Halls	8	144										
Load cell monitors/assay unit	23	414										
Assay units	18		Trad/Int Sgds		MSSP SPECS		NEUT DET		AEM ACC		NEUT DET + AEM ACC	
Item SG system capital costs per annum basis (10 year life span for equipment)		**Annual Cost/ item**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**	**Items**	**Total item Cost**
DA Sample Bottles		$ 16	173	$ 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 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
NaI 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	$ -	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				**$ 21,462**		**$ 30,578**		**$ 104,964**		**$ 1,260,264**		**$ 1,274,564**
Equip. spares&installation =% of annual cost		**10%**		**$2,146**		**$3,058**		**$10,496**		**$126,026**		**$127,456**
Total Annual Equipment Costs				**$23,608**		**$33,636**		**$115,460**		**$1,386,290**		**$1,402,020**
Annual equipment cost - repairs, trips, costs....as factor of equip. cost		**% of Equip. Cost Factor**										
Est. Annual Equipment Upkeep Costs		**10.0%**		**$2,360.8**		**$3,363.6**		**$11,546.0**		**$138,629.0**		**$140,202.0**
Total Annual Equipment Costs				**$ 25,968**		**$ 36,999**		**$ 127,006**		**$ 1,524,919**		**$ 1,542,222**
Inspections Needed per Option Regime				**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**		**# of Inspections**
No. routine inspections/yr				13		11		5		3		3
No. supplemental inspections/yr				6		2		3		3		3
No. Addl LFUA inspections/yr				8		0		0		0		0
No. PIV/yr				1		1		1		1		1
Annual Sample Procedure Costs per Option Regime		**Cost/ Sample**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**	**Sample**	**Sample Costs/Year**
DA Sample - procedures /yr		$ 700	115	$ 80,500	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				**$ 83,500**		**$ 56,900**		**$ 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%

EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL	Option A		Option B		Option C		Option D		Option 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	*18*		Trad/Int Sgds		MSSP SPECS		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				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)**		**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				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)**		**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 - burdened				**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. Type			**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**	**PDI**	**Cost (USD)**
Staff costs for routine inspection			78	$ 260,000	66	$ 220,000	30	$ 100,000	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		$ 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				**$ 237,150**		**$ 125,550**		**$ 74,400**		**$ 55,800**		**$ 55,800**
Inspector Office Costs by Insp. Type												
Staff office costs for routine inspection				$ 32,885		$ 41,738		$ 25,296		$ 18,972		$ 18,972
Staff office costs for suppl inspection				$ 1,581		$ 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				**$ 44,479**		**$ 50,170**		**$ 41,897**		**$ 41,897**		**$ 41,897**
Total annual labor/staff/sampling costs				**$ 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**	**$M**	**0.5**	**$M**	**1.8**	**$M**	**1.8**

CURRICULUM VITAE

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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** *Los Alamos National Laboratory* • 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** *Idaho National Laboratory* • 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 **Community Service:**	• Penn State Navigators Chapter, Student Leadership Team. • American Nuclear Society, Penn State Student Chapter. • Common Ground, Student Organizer. • Spring Break Service Trips, Orlando, FL, Atlanta, GA, Jacksonville, FL (2008-2011).