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Final Report of the Third International Meeting on Next Generation Safeguards

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Final Report
Third International Meeting on

Next Generation Safeguards

Safeguards-by-Design

December 14–15, 2010
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INTRODUCTION

The *Third International Meeting on Next Generation Safeguards*, hosted by the U.S. Department of Energy/ National Nuclear Security Administration's (DOE/NNSA) Office of Nonproliferation and International Security (NIS) on December 14 – 15, 2010 at the Washington Hilton Hotel in Washington, D.C., was a two-day technical meeting to discuss implementation of the Safeguards by Design (SBD) concept. There were approximately 100 participants from thirteen countries with representatives from government, industry, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), the European Atomic Energy Agency (Euratom), and the International Atomic Energy Agency (IAEA).

The primary objective of this meeting was to exchange views and provide recommendations on implementation of the SBD concept for four specific nuclear fuel cycle facility types: gas centrifuge enrichment plants; GEN III and GEN IV reactors; aqueous reprocessing plants; and mixed oxide (MOX) fuel fabrication facilities. The general and facility-specific SBD documents generated from the four working groups, which were circulated for comment among working group participants, are intended to provide a substantive contribution to the IAEA's efforts to publish SBD guidance for these specific types of nuclear facilities in the near future.

This effort was an extension of DOE/NNSA's Next Generation Safeguards Initiative (NGSI) program to study and identify SBD best practices and lessons learned, to engage industry on facilities planned in the United States, and to coordinate with the IAEA on the development of practical guidance documents for the application of SBD. A fundamental objective of this meeting was to advocate the need for SBD and to help the IAEA promote and institutionalize the concept of SBD as a tool for increasing the effectiveness and efficiency of international safeguards. Central to this effort is the argument that consideration of safeguards early in the facility design process can reduce the safeguards burden for both the operator and the IAEA.

BACKGROUND ON THE SAFEGUARDS BY DESIGN CONCEPT

The IAEA describes SBD as a concept in which facility designers and operators consider broad international safeguards requirements and features "from initial planning through design, construction, operation, and decommissioning." The objectives of SBD are to make the implementation of IAEA safeguards more effective and efficient and to help operators minimize costly and time-consuming redesigns and retrofits. The achievement of these goals could save States, industry, and the IAEA time, money, and effort – a mutually beneficial endeavor.

Often in the past, nuclear facility designers have added safeguards features to their plants following design completion or even after construction. Under the SBD concept, States, industry, and the IAEA would discuss safeguards requirements early in the design phase. Such early coordination and planning could influence decisions on key design features, such as chemical processing, equipment design, material storage and handling arrangements, and facility layout, in a manner that facilitates safeguards implementation. Thus, SBD has the potential to have a significant impact on the nonproliferation field by promoting intrinsic facility features that enable enhanced safeguards and thereby reduce the safeguards cost to the operator and the IAEA.

To address this long-term issue, the IAEA, DOE/NNSA, and other stakeholders recently have begun promoting the concept of Safeguards by Design. In October 2008, the IAEA hosted an international workshop to discuss how safeguards implementation could be improved through facility design and operations. One important recommendation from the meeting, published in "Facility Design and Plant Operation Features that Facilitate the Implementation of IAEA Safeguards" (STR 360)[1], was that the IAEA should continue engaging all stakeholders in the SBD process and create expert working groups on, *inter alia*, SBD principles based on facility type. The IAEA, with assistance from the European Commission Support Programme, currently is developing a document that will lay out the fundamental design features and measures that facilitate the implementation of international safeguards. The IAEA also has discussed plans to prepare facility-specific guidance based on Member State experience and expertise.

To complement these efforts, DOE/NNSA commissioned a U.S. National Laboratory team in 2008 to study the implementation of Safeguards by Design in support of NGSI efforts to strengthen international safeguards worldwide. These studies – which focus on best practices and lessons learned from former IAEA inspectors and include draft guidance documents for designers of different types of nuclear facilities – are aimed at further assisting the IAEA in defining overall objectives and developing practical guidance for the application of Safeguards by Design.

MEETING OVERVIEW

Summary of Day One (December 14, 2010):

The meeting was convened by Meeting Chair Kasia Mendelsohn, Director of DOE/NNSA's Office of Nuclear Safeguards and Security. The first day's agenda began with remarks by NNSA Administrator Thomas D'Agostino and a keynote address by Deputy Secretary of Energy Daniel Poneman, which provided an overview of the Obama Administration's nonproliferation and nuclear energy programs and policy objectives, including a comprehensive nuclear fuel services framework and NGSI. Both addresses also emphasized the importance of international partnerships and the need for communication between governments and private industry.

In the first plenary session on SBD program strategies, Mr. Bruce Moran, Head of the IAEA Safeguards Concepts and Approaches Section, elaborated on how SBD fits in with the IAEA Safeguards Department's long-term vision and how it will help address future safeguards challenges, particularly in light of an anticipated global expansion of civil nuclear power. Mr. Dunbar Lockwood of DOE/NNSA's Office of Nonproliferation and International Security followed with NNSA's views on SBD and comments on how its efforts complement those of the IAEA. The remaining plenary sessions focused on industry perspectives from safeguards implementation in nuclear reactors (Dr. Jeremy Whitlock, Atomic Energy of Canada, Ltd.), gas centrifuge enrichment plants (Mr. Peter Friend, URENCO, Ltd.), MOX fuel fabrication facilities (Dr. Michael McMahon, AREVA, Inc), and aqueous reprocessing plants (Dr. Tomonori Iwamoto, Japan Nuclear Fuel Limited).

Summary of Day Two (December 15, 2010):

During the second day of the meeting, four working groups were tasked with developing guidance on SBD implementation at each of the four facility types featured the previous day. All groups included safeguards and facility experts from a variety of organizations and backgrounds. Each group produced a document reporting on its discussions of facility-specific SBD ideas and best practices. These reports are included in this report as appendices 2, 3, 4 and 5. NNSA plans to use these working group reports to help promote the concept of Safeguards by Design and, in collaboration with industry and the IAEA, to develop generic guidance documents for these specific types of facilities.

OBSERVATIONS AND AREAS OF GENERAL AGREEMENT

During the closing plenary session of day two, the working group moderators and the Meeting Chair presented a number of generally agreed upon (albeit not necessarily consensus) observations from throughout the meeting. These included:

- Presenters utilized or accepted the IAEA's definition of SBD as "an approach whereby international safeguards considerations are fully integrated into a nuclear facility from the initial planning through design, construction, operation, and decommissioning."

- SBD is a longstanding concept, but it has never been broadly or systematically implemented.

- Because interactions between and among facility designers, national regulators and operators, and the IAEA typically are very formal and must go through State institutions, there currently is little precedent or opportunity for, or guidance on early and direct industry engagement with the IAEA on safeguards considerations. A structured process in which the IAEA, the State (e.g., via the State System for Accounting and Control of nuclear material (SSAC)), and industry could engage with each other early in the design process would be helpful.

- The SBD concept has gained prominence in recent years as the IAEA and other key stakeholders have indicated support for moving toward implementation of the concept in a more structured manner.

- There are a number of past ad-hoc examples of Member States or nuclear industry incorporating safeguards into a facility's design process. These examples include Atomic Energy of Canada Limited (AECL)'s design of its Advanced CANDU Reactor (ACR 1000) and recent discussions between Sweden, Finland, and the IAEA on the design of new geological repository facilities.

- IAEA safeguards approaches for different facilities and facility types are confidential, and there is little advance guidance for industry and other stakeholders as to which safeguards requirements are applicable and which recommendations should be made for specific facilities. IAEA-published guidance on safeguards considerations for specific facility types would be useful to help designers and operators gain a better understanding of the IAEA's requirements, such as key measurement points (KMPs), material balance areas (MBAs) and containment and surveillance (C/S).

- SBD will require regular consultations early in the design process among key stakeholders – designers, operators, government officials, representatives from regulatory agencies, and safeguards experts from inspectorates.

- SBD is focused on new facilities.

- SBD is a voluntary and collaborative process; IAEA requirements do not mandate including safeguards requirements in the preliminary facility design phase. The IAEA requires that facility design information be provided to the IAEA "as soon as the decision to construct or to authorize construction has been taken," and no later than 180 days before construction begins. SBD, however, would necessitate much earlier (and therefore voluntary) collaboration between the facility designer, national regulators, operators, and the IAEA.

- SBD should benefit all stakeholders.

- SBD should make the implementation of international safeguards more effective and efficient and reduce project management risk (e.g., costs, scheduling, and licensing) to the designer and operator.

- For existing types of facilities, it is important to identify best practices to optimize the facility design for new builds.

- For new types of facilities with new technologies, it may be necessary to identify innovative and advanced safeguards technologies and concepts in cases where the current toolkit is not sufficient.

- The IAEA, government representatives, nuclear industry and other stakeholders should continue to work together to identify strong business or economic cases that demonstrate the benefits of Safeguards by Design. Strong business cases that demonstrate specific examples in which the SBD process saved operators' and/or designers' time and money will go a long way toward promoting broader support for SBD among all stakeholders.

- Producing SBD guidance reports will be an important step in helping SBD move from a general, abstract concept to specific practical guidance and application. It is clear that the IAEA must take a lead role in developing written guidance for the application of SBD. The upcoming publication of the SBD main principles and concepts document under preparation by the IAEA, with assistance from the European Commission Support Programme, will help build positive momentum in this direction.

- NNSA's NGSI will work in collaboration with the IAEA and in consultation with industry to help develop SBD guidance documents for specific types of nuclear facilities.

WORKING GROUPS

NNSA assigned participants to one of four working groups based on their respective professional expertise or experience with certain facility types. The four working groups drafted reports that describe specific ways in which SBD can be applied to the design process of different nuclear facility types. The reports from the four working groups: gas centrifuge enrichment plants; aqueous reprocessing plants; MOX fuel fabrication plants; and GEN III and GEN IV reactors – are attached in Appendices 2, 3, 4 and 5 respectively. These working group reports are intended to inform the development of future Safeguards by Design guidance documents for industry (designers and operators), and are meant to support the IAEA's efforts to publish SBD guidance for specific types of nuclear facilities in the near future. *The recommendations in these working group reports received broad support, but did not necessarily receive consensus approval.*

FINAL WRAP-UP SESSION AND CLOSING PLENARY GOALS

Ms. Kasia Mendelsohn chaired the wrap-up session and led the plenary in a broad discussion of key next steps. During this session, working group moderators described the working group discussions and main outcomes. Ms. Mendelsohn also provided an overview of the meeting's broader themes, discussions and conclusions. In summarizing the meeting, she reiterated that its goals were to promote information exchange, identify topics for collaboration, and produce papers that could form the basis for substantive guidance on implementation of SBD in specific types of nuclear facilities. Ms. Mendelsohn concluded that discussions during the meeting helped advance SBD beyond abstractions and general principles.

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[1] IAEA - International Atomic Energy Agency. *Facility Design and Plant Operation Features that Facilitate Implementation of IAEA Safeguards*. IAEA Report STR-360, IAEA, Vienna, Austria. February 2009.

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APPENDIX 1: SUMMARY OF PLENARY PRESENTATIONS

OPENING REMARKS: MR. THOMAS P. D'AGOSTINO, DOE/NNSA

Mr. Thomas D'Agostino, Undersecretary for Nuclear Security at the U.S. Department of Energy and Administrator of the National Nuclear Security Administration, provided opening remarks to establish the context for the meeting. Mr. D'Agostino's remarks highlighted the unique role of DOE/NNSA's Next Generation Safeguards Initiative among U.S. nonproliferation programs and priorities. Mr. D'Agostino also emphasized the importance of international partnerships, among governments and with private industry, in achieving nonproliferation and nuclear security goals.

Commenting on NNSA's efforts to complement the IAEA's work, Mr. D'Agostino stated that "NNSA is working with the IAEA to advance and institutionalize Safeguards by Design so that international safeguards measures are more fully integrated into new nuclear facilities, along with safety and security measures from the outset of the design process. This will help operators avoid costly and time-consuming redesign efforts, save the IAEA time, money, and effort, and ultimately enhance the effectiveness and efficiency of safeguards implementation." Mr. D'Agostino closed by noting that this meeting was an opportunity "to continue moving forward with the recent progress that the IAEA, NNSA, and others have made. We hope that… our collaboration at this meeting will contribute positively to the IAEA's development of facility-specific Safeguards by Design guidance documents."

KEYNOTE ADDRESS: MR. DANIEL PONEMAN, DOE

Mr. Daniel Poneman, U.S. Deputy Secretary of Energy, provided an overview of the Obama Administration's nonproliferation and nuclear energy programs and policy objectives, including a comprehensive nuclear fuel services framework.

Mr. Poneman called for industry, governments, regulators, and inspectorates to form a strong partnership to "develop the concept of Safeguards by Design – a potentially transformational concept that meets both public and private sector goals." He added, "with Safeguards by Design, we envision an intersection between good governance, good policy, and good business."

SAFEGUARDS BY DESIGN PROGRAM STRATEGIES

IAEA Safeguards by Design Program: Mr. Bruce Moran, IAEA

Mr. Bruce Moran, Head of the IAEA Safeguards Concepts and Approaches Section, delivered a presentation on the Agency's SBD program, explaining the program's history, goals, accomplishments, and plans for the future.

Mr. Moran stated that there are some precedents for Safeguards by Design that have emerged over the last two or three decades, but he argued that a "structured process" is needed.

In laying out the Agency's view on SBD's overarching principles, he noted that, inter alia: all stakeholders should realize some benefit; sensitive and proprietary information should be protected; and an understanding of the importance of effective safeguards should be enhanced. Mr. Moran stated that SBD's goals include: (1) increasing safeguards efficiency with equivalent or improved safeguards effectiveness; (2) eliminating redundancies and inefficiencies through consideration of safeguards objectives and requirements early in the design process; and (3) promoting understanding of the importance of safeguards within the nuclear industry.

Mr. Moran stressed that Safeguard by Design should be a voluntary, collaborative process for optimizing the design of facilities and noted the need to be proactive in promoting the potential benefits for stakeholders, including minimizing projects risks (e.g., cost, scheduling, licensing).

U.S. NGSI Safeguards by Design Program: Mr. Dunbar Lockwood, DOE/NNSA

Mr. Dunbar Lockwood, the federal program manager and Team Leader for the U.S. NGSI SBD program, delivered a presentation outlining the goals, objectives and key elements of the program. Mr. Lockwood described the main activities of the NGSI program, initiated in 2008, to help promote SBD as a global norm. These include working with international safeguards experts at U.S. National Laboratories, engaging industry and the IAEA, sponsoring technical papers for the INMM Annual Conference and other venues, and preparing lessons learned studies and "model" SBD guidance documents with the aim of supporting IAEA efforts to develop internationally accepted, facility-specific guidance.

From the NGSI perspective, Mr. Lockwood stated that SBD has four main objectives: (1) design new civil nuclear facilities that meet national and international nuclear safeguards requirements; (2) make implementation of safeguards at such facilities more effective and efficient; (3) avoid costly and time-consuming redesigns and retrofits, minimize disruptions, and protect sensitive information; and (4) design facilities so that misuse of the facility and/or diversion of nuclear material is more technically difficult and easier to detect if attempted.

Mr. Lockwood emphasized the distinction between identifying best practices for existing facility types and developing advanced concepts and novel technologies for new facility types. He also stressed that SBD will help retain safeguards knowledge by training the next generation of safeguards experts both in government and industry.

Regarding the question of whether SBD implementation would apply to facilities in nuclear weapons states, Mr. Lockwood noted that there is some likelihood that under the U.S. Voluntary Offer Agreement, the IAEA might select an enrichment plant or future reprocessing plant for the application of international safeguards. He added that if U.S. technology is exported for facilities in a non-nuclear weapons state, those facilities will be under IAEA safeguards.

In closing, Mr. Lockwood identified three main challenges going forward: (1) ensuring industry buy-in (communicating to designers and operators that SBD is in their best interest in terms of project risk management); (2) getting the right stakeholders together early in the design process while decisions are being made; and (3) generating practical ideas in terms of plant layout, technology, etc. that designers and operators can actually apply and implement.

SAFEGUARDS BY DESIGN LESSONS LEARNED

Enrichment Plant Safeguards by Design Lessons Learned: Mr. Peter Friend, URENCO, Ltd.

Mr. Peter Friend, Head of Security and Safeguards, URENCO Ltd. delivered a presentation on SBD lessons learned and best practices from safeguarding URENCO gas centrifuge enrichment plants (GCEPs) in Europe. In this context, he noted that:

- Informal discussions with safeguards inspectors can be useful for inspectorates to learn about new plants and for an exchange of ideas on the safeguards approach;
- Formal negotiations on the safeguards approach should include the operator, Member State, the IAEA (and regional inspectorates, as appropriate);
- Centrifuge enrichment technology must be protected, for example by defining precise routes for limited-frequency unannounced access (LFUA) inspections and moving instrument displays to hide sensitive data;
- Inspectors must have access to cylinders in feed stations, process pipework, process valves, centrifuges, and sampling points;
- Cascade halls should include little other than UF6 equipment to shorten inspection routes; and
- Valve/flange combinations in cascades should be kept to a minimum or even eliminated.

Mr. Friend emphasized that safeguards verification must not interfere with the commercial operations of a uranium enrichment facility, and that plant operators and designers need to understand both the safeguards inspection measures and security requirements agreed to by Member States, the IAEA, and regional inspectorates.

Mr. Friend added that URENCO would prefer a high frequency of visits by inspectors to any introduction of intrusive, untested safeguards monitoring equipment. He also noted that much of URENCO's opposition to the proposed use of novel safeguards technologies arises from the potential for an increase in the capital cost and a delay to the construction of new GCEPs. These facilities operate in a highly competitive world market in which many competitors' plants have no international safeguards inspections at all. In this commercial climate, GCEP operators whose plants are subject to IAEA inspection will naturally resist novel safeguards developments that could increase their costs.

Nuclear Reactor Safeguards by Design Lessons Learned: Dr. Jeremy Whitlock, Atomic Energy of Canada Limited (AECL)

Dr. Jeremy Whitlock of AECL delivered a presentation on SBD lessons learned from AECL's experience with the incorporation of safeguards considerations into the design of Canada Deuterium Uranium (CANDU) reactors. Whitlock and his collaborators adapted elements of the "Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems" to determine and rank, in a simple qualitative way, potential diversion pathways in the new ACR-1000 design. These were then used to determine whether the new elements of the reactor design posed new safeguards challenges relative to the traditional CANDU, and to identify where design changes might facilitate the application of safeguards in a manner that would provide benefits to both the IAEA and the reactor operator. He also discussed a safeguardability assessment of AECL's MACSTOR-400 dry storage technology that shed light on how unattended remote monitoring of spent fuel in such a facility could be achieved.

Dr. Whitlock observed that the analyses performed by AECL were qualitative in nature, involved both safeguards and designer personnel, and did not require extensive time or cost. They nevertheless yielded valuable insights into how design features might be modified to enhance their safeguardability.

Based on AECL's expereince, Dr. Whitlock suggested the following lessons:

- SBD must be a 3-way communication among the designer, the State's SSAC, and the IAEA;
- It is important to emphasize the business benefits of SBD to the designer;
- There is a need to allow for the evolution of technology throughout the life of a facility; and
- Industry has genuine concerns about "scope creep" and requirements that change over time.

Dr. Whitlock stressed the importance of promoting an "SBD culture" in which facility designers and safeguards experts work closely together.

Fuel Fabrication Plant Safeguards by Design Lessons Learned: Dr. Michael McMahon, AREVA Inc.

Dr. Michael McMahon of AREVA Inc., U.S., delivered a presentation on SBD lessons learned from AREVA's experience incorporating safeguards considerations into the design of the MELOX MOX fuel fabrication plant.

He pointed out that "the Euratom/MELOX 'Safeguards During Construction' interaction is an early practical example of the SBD-type approach." According to Dr. McMahon, it "achieved a 'win-win' situation of meeting all of Euratom's objectives without penalizing plant productivity or impacting operator health or safety. Euratom inspectors involved in the construction phase gained extensive knowledge of MELOX's technical systems and production processes. Efficient and cost-effective implementation [was achieved] by taking advantage of existing operator equipment and production information." Dr. McMahon also stated that "involvement of Safeguards Authorities earlier in the design phase of nuclear facilities should result in similar mutual benefits."

Reprocessing Plant Safeguards by Design Lessons Learned: Dr. Tomohiro Iwamoto, Japan Nuclear Fuel Limited (JNFL)

Dr. Tomonori Iwamoto of Japan Nuclear Fuel Limited presented "Safeguards Lessons Learned from Rokkasho Reprocessing Plant (RRP)." Dr. Iwamoto described how the safeguards system at RRP addresses the major technical findings of the IAEA's consultative forum for large scale reprocessing plant safeguards (LASCAR) on approaches to safeguarding large reprocessing plants, including solution measurement monitoring, the Integrated Head-End Verification System, the MOX Storage Containment and Surveillance System, the Automatic Sampling Authentication System, and the Integration Inspection Information System. Dr. Iwamoto discussed the approach to splitting signals from the Solution Measurement Monitoring System (SMMS) at RRP and ideas for developing an Advanced Solution Measurement Monitoring System to measure plutonium quantities directly, as well as possible limitations on the safeguards effectiveness of process monitoring during plant start-up and shutdown operations.

During an overview presentation on Safeguards by Design Lessons Learned, Dr. Yusuke Kuno of the Japan Atomic Energy Agency and the University of Tokyo discussed his notion that the "proliferation resistance" of a closed fuel cycle could be enhanced by technical measures that make the product of reprocessing unattractive for diversion. Dr. Kuno argued that, in states for which the IAEA has already made a “broader conclusion” at the state level, safeguards should pay more attention to operational transparency to confirm the absence of misuse of nuclear facilities rather than rely on the “mechanistic” pursuit of traditional safeguards. He described Japan’s experience with the implementation of integrated safeguards at the JNC-1 site, covering both specific examples of safeguards instrumentation and his ideas on the contribution SBD can make to integrated safeguards. He concluded that randomly scheduled inspections under integrated safeguards could reduce inspection days per year by about half at a plutonium fuel fabrication facility, with the benefit of significantly reducing the impact of inspections on facility operation.

APPENDIX 2: ENRICHMENT FACILITIES WORKING GROUP REPORT

EXECUTIVE SUMMARY

The key safeguards concerns specific to GCEPs include diversion of declared materials, excess production of LEU (using undeclared feed), and direct production of HEU. A diverse range of stakeholders is currently investigating and developing tools and methods to enhance the application of international safeguards at enrichment facilities. Current safeguards challenges include: (1) independently assessing the installed separative capacity as declared in the Design Information Questionnaire; (2) protecting classified and/or proprietary information associated with the separation technology; and (3) working under budgetary constraints. Technical meetings and workshops such as NGS3 offer stakeholders the opportunity to discuss these challenges with individuals from different fields of expertise.

Some of the safeguards measures under evaluation include short-notice random inspections, continuous process monitoring, shared use of operator data, continuous item monitoring, and on-site analytical capabilities. The working group discussed design suggestions and proposed next steps to address current needs and concerns. Although some measures are already being investigated, other design suggestions will require research and development.

INTRODUCTION

The objective of the Enrichment Facilities Working Group, as presented by the Third International Meeting for Next Generation Safeguards (NGS3) organizer, was to compile a collection of design-related suggestions and recommendations that could be provided to facility designers to allow for the most efficient implementation of international safeguards at Gas Centrifuge Enrichment Plants (GCEPs).

Currently, the world enrichment capacity is approximately 56 million kilogram separative work units (SWU) per year, with 22.5 million SWU/year in gaseous diffusion and more than 33 million SWU/year in gas centrifuge plants. While gaseous diffusion plants provide about 40% of the current world enrichment capacity, they are being phased out and more GCEPs are being constructed. Another 34 million SWU/year of capacity is under construction or planned for the near future, based almost entirely on gas centrifuge separation technology.[1] The Appendix 2 Attachment provides a list of the world's enrichment plants.

The working group was comprised of a broad variety of key stakeholders from around the world. Twenty-five participants represented seventeen separate organizations. A complete list of the working group participants is provided at the end of this Appendix. Approximately 40% of the participants have worked at operating plants or are involved in the design and construction of new plants. Prior to the meeting, a document containing read-ahead material was provided by the meeting's organizers to stimulate the working group's thinking and included examples of design considerations and suggestions for five topical areas:

- Design Information Verification
- Nuclear Material Accountancy
- Containment and Surveillance
- Verifying Absence of Undeclared Operations

- Other Design Considerations

In preparation for the meeting, participants were asked to identify possible improvements to key design features and to present their ideas to the working group during the discussions. To assist with developing design feature suggestions, working group members were provided a “model” Safeguards by Design (SBD) guidance document produced for the U.S. Department of Energy/National Nuclear Security Administration.[2] This document promotes the International Atomic Energy Agency’s (IAEA) objectives of avoiding costly and time-consuming redesign work or retrofits to new nuclear facilities and providing for more effective and efficient implementation of international safeguards. These objectives were the underlying theme of the working group discussions that also addressed the IAEA objectives for the detection of:

- Diversion of declared materials;
- Undeclared production of excess low-enriched uranium (LEU); and
- Undeclared production of highly enriched uranium (HEU).

DAY ONE—PLENARY SPEAKERS

During the first day of the meeting, two of the plenary speakers presented papers with direct relevance to the Enrichment Facilities Working Group. Mr. Bruce Moran, the IAEA Section Head for the Concepts and Approaches Section, outlined the IAEA’s SBD objectives in his presentation, “Safeguards by Design Lessons Learned.” Mr. Peter Friend, URENCO’s Head of Security and Safeguards, provided an industry view in his presentation, “URENCO’s Experience of Safeguards by Design in Gas Centrifuge Enrichment Plants.” Both of these presentations provided beneficial insights for the subsequent working group discussions. Mr. Moran stressed that it will be important to emphasize that SBD should be a voluntary undertaking, and that all of the key stakeholders, such as the international safeguards community and plant designers and operators, should be included in the ongoing dialogue.

Mr. Friend pointed out that the design of URENCO’s facilities has evolved over the years to provide for more effective safeguards implementation. He noted that in the preconstruction design phase of new facilities, URENCO did not allow for the use of new and untested safeguards measures and emphasized that SBD is relevant only at facilities that require international safeguards inspections.

DAY TWO—ENRICHMENT FACILITIES WORKING GROUP SESSION ACTIVITIES

Working group moderator Mr. Michael Whitaker opened the session with an overview of the working group’s agenda and a review of the first day’s key goals. These included:

- Identifying potential benefits of SBD to the operators and the inspectorate;
- Bringing stakeholders together to discuss international safeguards considerations at an early phase in the design process;
- Identifying issues involving field trials of equipment, access needs, and changes in the facility;
- Providing designers a list of suggestions;
- Integrating nontraditional safeguards activities; and
- Addressing major challenges (e.g., acquiring industry buy-in, getting the right stakeholders at the table, and generating practical ideas that can be implemented).

These opening remarks were followed by a presentation from DOE/NNSA's Mr. Brent McGinnis, entitled "Implementing Safeguards by Design at Gas Centrifuge Enrichment Plants."

The working group discussed each of the five topical areas from the read-ahead material for approximately 30-45 minutes. General points raised during the discussion included the following:

- Conflicting objectives exist in designing safeguards approaches for facilities;
- A safeguards approach needs to be fully effective;
- Technology holders are obligated to protect sensitive nuclear information;
- The IAEA is obligated to minimize intrusiveness into plant operations;
- IAEA resources (staff and finances) are limited;
- Plant operators desire minimal inspection cost and impact;
- Safeguards approaches need to be balanced with respect to safety;
- Safeguards design features that would require minimum-to- moderate levels of R&D to implement need to be addressed;
- New design features may be needed; and
- Significant design changes may be required.

There were detailed discussions on the meaning of "minimal costs." The ultimate goal is to develop new techniques that both optimize the implementation of safeguards and reduce the costs to both the operator and the inspectorate, thus improving the effectiveness and efficiency of safeguards implementation.

DISCUSSIONS ON DESIGN SUGGESTIONS

A summary of the general discussions and individual comments for each topical area are provided below. *It is important to note that the individual comments included below do not necessarily represent the consensus of the entire group.*

Design Information Verification

Design Information Verification (DIV) is undertaken throughout the entire lifetime of a facility, from the provision of design information to the IAEA through decommissioning. DIV includes verifying that no undeclared changes to the declared design have been made and confirming that the operation of the facility, the configuration of the piping, and the operation of the feed and withdrawal (F/W) stations are all consistent with the State's declaration. It was suggested that the IAEA should continue to consider national information and technology security issues in developing its safeguards approach for GCEPs. Goals for improving the facility design include effective implementation of material accountancy by minimizing the material unaccounted for (MUF) and improving the detection probability for undeclared activities by enhanced transparency of facility operations. For SBD to be effective, conversations with the IAEA should be initiated early during the conceptual design stage of the facility.

On the subject of general design, the working group participants expressed ideas about the cascade hall design. Some participants suggested that the size of the cascade hall should be minimized, while others argued that larger and more open cascade halls with greater distances between cascades would minimize clutter and facilitate visual observation. Some members also suggested: (1) limiting the equipment in the cascade halls to include only items directly related to separation of uranium isotopes,

(2) decreasing the number of potential locations for F/W stations, and (3) reducing the amount of piping. In addition, some features embedded in the design, such as straight pipes that minimize the potential for process hold up, make IAEA verification easier.

The working group addressed the challenge of complying with the IAEA's obligation to verify the declared construction and operation of each facility. A typical GCEP can be difficult to verify for inspectors with limited experience in enrichment process design. In order to facilitate the inspection process, it was suggested that designer/operators should clearly label all piping wherever possible. Some working group members suggested that simplified piping outside of the cascade could facilitate DIV. Designers also should use designs that allow IAEA inspectors unobstructed visual access to relevant points of access and avoid complex piping configurations (e.g., by embedding piping in floors or through walls). In addition, feedback from some working group members suggested that three-dimensional laser range finder technology could be used to more efficiently verify process designs; however, some participants noted that this method cannot be used in areas with classified items and where business proprietary information could be compromised over time.

Some participants suggested that GCEP plant designs should allow for inspector access to all areas of the facility where nuclear material is identified in the Design Information Questionnaire. It was also suggested that facilities provide access to all UF_6 areas and provide an ability to verify the identity of the UF_6 cylinders in the F/W stations (e.g., through viewing windows).

SUGGESTED DESIGN CONSIDERATIONS FOR IMPROVING DIV ACTIVITIES:

- Perform DIV activities from the provision of design information through facility decommissioning;
- Develop facilities that allow the IAEA access to all areas containing nuclear material
    - Use simple piping configurations that allow for unobstructed visual verification of declared piping paths
    - Ensure that the IAEA has the opportunity to verify and maintain continuity of knowledge on any piping that has to be concealed
- Identify overlaps between plant design considerations and activities that support DIV inspections; develop designs that benefit both operations and inspections
    - Minimize size of cascade halls
    - Simplify piping
    - Minimize "non-safeguards-relevant" equipment
    - Provide clear, definitive labeling of piping
    - Minimize sampling and other process connections that have F/W capability
    - Avoid valve/flange combinations where possible
- Provide capability to confirm cylinders identity in autoclaves/heating chests/cooling stations (e.g., viewing windows);
- Create databases of lessons learned from operators/designers/inspectors; and
- Evaluate applicability of 3D laser range finder technology to detect changes in design.

Nuclear Material Accountancy

Two major activities were identified to detect the diversion of declared nuclear materials: (1) verification of nuclear content; and (2) minimization of MUF. Support of these activities will require process instrumentation that can be shared by the operator. In many cases, the same information that operators need for routine plant operations is applicable to IAEA verification activities (though it should be noted that inspectors do not need all of the operators' process data). For example, cylinder weights measured by accountability scales and load cells or enrichment levels at select points, if properly authenticated, could be provided to inspectors. Currently, the IAEA verifies GCEP operators' declarations mainly through the use of its own measurement equipment; the working group questions this duplication of effort. It was suggested that the IAEA use the same instrumentation wherever possible, provided data authentication concerns can be resolved.

Participants noted that diversion scenarios for storage and process areas are different and should be assessed separately. There is a need to accurately account for all flows into and out of the process material balance area. Continuous monitoring of material flows at the plant level is challenging and some measurement methods are considered unacceptably intrusive. Improved accuracy and precision are needed for on-line and unattended verification of the enrichment and quantity of UF_6 material flows.

Expressing the view that IAEA inspectors collect too many samples, some participants suggested consideration be given to a new safeguards approach or process design change to help reduce sampling frequency.

SUGGESTED DESIGN CONSIDERATIONS FOR IMPROVING NUCLEAR MATERIAL ACCOUNTANCY ACTIVITIES:

- Minimize the MUF
- Identify process instrumentation where output data can be shared; identify methods to facilitate authentication
  - Accountability scales
  - Load cells
- Establish capability for the IAEA to measure the "process" material balance
- Identify design options that would reduce cylinder sampling frequency

Containment and Surveillance

The working group discussed the potential for reducing the residence times for cylinders in storage awaiting feeding, or prepared for shipment (e.g., by tagging the cylinders to permit unattended monitoring and measurements). The residence time could potentially be eliminated altogether, and any reduction would help to reduce the verification burden at the facility. A unique cylinder identification (ID) system could solve a number of problems and would allow for portal monitoring. Some participants suggested the IAEA could use a barcode system with a unique ID to increase the efficiency of physical inventory verification. Radio-frequency identification technology can be complex and expensive, but simple barcodes (engraved in steel) would be helpful. A standardized unique ID to facilitate tracking of cylinders used in international commerce was suggested.

The working group discussed the use of linear/simplified movement of cylinders within a plant. Some, however, expressed the need for flexibility for cylinder movements. For example, there may be an operational need for deviation from regular routes.

Some of the working group participants emphasized the need for a simple physical layout where the material flow has few diversion paths, avoids unnecessary entry/exit, and maintains a linear flow.

SUGGESTED DESIGN CONSIDERATIONS FOR IMPROVING CONTAINMENT AND SURVEILLANCE ACTIVITIES:

- Provide unique ID for cylinders for use with automatic reading devices;
- Utilize only linear/simplified movement of cylinders within plant;
- Provide capability for monitoring all F/W points; and
- Evaluate alternative process surveillance and monitoring systems.

Detecting Undeclared Operations

To detect undeclared operations, IAEA inspectors look for changes in process configurations. Facility licenses issued by States require the incorporation of a configuration control program by the facility operator. The current IAEA GCEP safeguards approach relies on limited-frequency unannounced access (LFUA) to the cascade. Measures associated with LFUA inspections include visual access, environmental sampling, nondestructive assay measurements on header pipes, and direct sampling of cascade header pipes.

Some working group members expressed concern that continuous process monitoring could disclose proprietary information. There may be a need to design an information barrier that withholds proprietary information from inspectors while still allowing them to meet their verification objectives. This might also be accomplished by providing inspectors with the ability to analyze data without saving it. In addition, visual inspections may allow for access to sensitive, proprietary, and export-controlled information. Automated shrouding of instrument readouts can be an effective and efficient method to protect sensitive information during visual inspections.

One working group member suggested either the continuous presence of a local IAEA inspector at a GCEP – or an unlimited number of unannounced inspections. Some of the working group members stated they would prefer a high frequency of inspections to the introduction of intrusive, untested safeguards monitoring equipment.

Some working group participants stressed the need to make cylinder nameplates readable and visually accessible and to store cylinders in a configuration that allows for easy identification. In addition, some argued that a cylinder tracking system could be beneficial to inspection performance. A facility should have the capability to provide the IAEA with a list of the exact locations of all cylinders onsite and to quickly locate any cylinder selected by the IAEA from the inventory list. Additionally, the facility should afford the IAEA access to all areas onsite where a cylinder might be located.

Some working group participants expressed national security and proprietary concerns associated with the provision of detailed cascade halls specifications. Facility operators currently provide a well-defined inspection route to protect sensitive information. In addition, all sampling and F/W locations should be visually accessible to the IAEA. The IAEA will need the capability to verify that nuclear materials are present only in declared process piping, vessels, and declared cylinders. Some participants said that a 3D laser range finder, coupled with a gamma imager, could potentially be used to verify absence of nuclear material in observable, non-process pipes.

The working group suggested further investigation into the optimum location of product header pipe enrichment monitors and the possibility of making a simple instrument for continuous enrichment monitoring.

SUGGESTED DESIGN CONSIDERATIONS FOR IMPROVING VERIFICATION OF ABSENCE OF UNDECLARED OPERATIONS:

- Investigate optimum locations for product header-pipe enrichment monitors;
- Evaluate use and value of process monitoring including:
    - Scales and mass spectrometers
    - Flow monitors
    - Enrichment monitors
- Provide for identification of cylinders at F/W stations;
- Identify parameters that demonstrate the facility operates as declared (e.g., swipe sampling and accountancy control in combination with revised LFUA system);
- Model scenarios for reconfigured cascades – identify potential indicators;
- Investigate applicability of a 3D laser range finder and gamma imager to verify absence of nuclear material in non-process pipes.

Other Design Considerations

The working group addressed the global issues of SBD within the international nuclear nonproliferation regime. The need to include <u>all</u> stakeholders in SBD was discussed.

Some working group members commented that opposition to new safeguards technologies derives from potential capital cost increases and construction delays. GCEPs operate in a highly competitive world market, in which not all plants are subject to international safeguards. GCEP operators whose plants are subject to IAEA inspection will therefore have serious concerns regarding novel safeguards developments that could increase costs.

Some working group members commented that deployment of new technologies would not necessarily increase production costs. For example, stakeholders could develop mechanisms for performing collaborative field-testing. It is important that equipment developers be introduced to and involved in the application of SBD. There is concern about the time required for development, testing, and IAEA approval of new safeguards technologies (a process that can take up to ten years). Designers prefer equipment that has been demonstrated and proven. This underscores the need for safeguards equipment designers to be involved in SBD from the beginning of the facility design process so that new equipment can be designed and tested before it is implemented.

There was consensus among the working group that SBD should not be a regulatory requirement. Stakeholders would like to receive generic guidance for the long-term life of the facility, and this should be neither performance-based nor prescriptive. SBD should be based on the safeguards inspectorates' objectives and should not be driven by the equipment industry.

OTHER SUGGESTED DESIGN CONSIDERATIONS:

- Inform equipment and plant developers of SBD concepts/application;
- Develop tools based on operational experience;
- Develop and evaluate performance-based guidance versus prescriptive requirements taking into account operator needs and constraints; and
- Develop mechanisms among various stakeholders for performing collaborative field testing.

NEXT STEPS

The working group recommended the following next steps:

1. Identify potential operator benefits that could be achieved through sharing process data (e.g., with the IAEA, Euratom, ABACC, national authorities, etc.). For example:
    a. Reduced on-site inspections or inspection activities (e.g., cylinder re-weighing)
    b. Automation of repetitive verification activities
    c. Reduced cylinder holding times

While also considering that sharing process data may:
    d. Require increased or more complex security related expenditures
    e. Cause "false positives" upon equipment malfunction
    f. Lead to frequent equipment calibration/maintenance
    g. Divulge classified or commercially sensitive information

2. Identify specific operator data (equipment) that could be shared.
    a. Identify specific gaps in the current application that could be addressed by sharing data from specific operator equipment
    b. Determine issues, concerns, and challenges regarding sharing data from specific operator equipment
    c. Examine data security and authentication
    d. Examine the impact of equipment malfunction, interruption, etc.

3. Develop performance requirements for new safeguards equipment.
    a. Perform a cost-benefit analysis
    b. Identify the potential impact to operations
    c. Develop "scenario based" safeguards systems requirements (based on typical designs and plant size assumptions)

4. Identify individual or integrated system elements that would provide for the sharing of process data in future nuclear facilities.

5. Investigate design features that would provide for random, remote inspections that could reduce the frequency or intensity of routine activities performed by the inspectors that adversely affect operations.

6. Examine the inspector and operator benefits of a standardized system for UF_6 cylinder identification and more timely cylinder tracking – for example, in verifying transfers (internationally and between facilities), inventories, and flows within facilities and any implications for facility design.

7. Establish more detailed technical objectives and performance targets for applying IAEA safeguards at enrichment plants.
    a. Establish what must be achieved by the IAEA (the next level of detail beyond the three primary objectives)
    b. Identify techniques available to meet these objectives and performance targets
    c. Collect lessons learned from IAEA inspectors

8. Collect lessons learned from inspected GCEP operators and assess whether the current type and level of surveillance is both effective and of minimal impact to operations.

9. Present papers regarding SBD issues during the 2011 Institute of Nuclear Materials Management special session on GCEP safeguards, with emphasis on:
    a. Progress on specific investigations/studies identified above
    b. Lessons learned from operators
    c. IAEA perspectives on design features that provide for efficient application of international safeguards
    d. IAEA's relevant objectives and performance requirements

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NOTES

[1] Laughter, M. (2009). *Profile of World Uranium Enrichment Programs - 2009 (ORNL/TM-2009/110).* Oak Ridge: Oak Ridge National Laboratory.

[2] Laughter, M., J. McCowan, B. McGinnis, J. Morgan, and M. Whitaker, *Implementing Safeguards-by-Design at Gas Centrifuge Enrichment Plants*, ORNL/TM-2010/87, December 2010.

APPENDIX 2 – ATTACHMENT: WORLD ENRICHMENT PLANTS

State	Plant Name/Location	Owner/Operator	Type	Status	Capacity (kg SWU/year)
Argentina	Pilcaniyeu	CNEA	Gaseous diffusion	Standby/planned	20,000
Australia	Lucas Heights	AAEC	Centrifuge	Shutdown/dismantled	Laboratory
Brazil	Aramar	Brazilian Navy, CNEN	Centrifuge	Operating	9,000
	Resende	INB	Centrifuge	Operating/under construction	120,000
China	Heping	CNNC	Gaseous diffusion	Operating	400,000
	Lanzhou	CNNC	Gaseous diffusion	Shut down	500,000
	Shaanxi—Hanzhong	CNNC	Centrifuge	Operating	500,000
	Lanzhou	CNNC	Centrifuge	Operating	500,000
	Phase 4 (Hanzhong or Lanzhou)	CNNC	Centrifuge	Planned	500,000
France	Pierrelatte GDP	CEA	Gaseous diffusion	Shut down	500,000
	Georges Besse—Tricastin	Eurodif	Gaseous diffusion	Operating	10,800,000
	Georges Besse II—Tricastin	Areva	Centrifuge	Under construction	7,500,000
Germany	Gronau	Urenco	Centrifuge	Operating	2,200,000
				Planned	2,300,000
India	BARC, Trombay	DAE	Centrifuge	Operating	Pilot
	Rattehalli Rare Materials Plant, Mysore	IREL/DAE	Centrifuge	Operating	4–10,000
Iran	Natanz PFEP	AEOI	Centrifuge	Operating	Pilot
	Natanz FEP	AEOI	Centrifuge	Operating/under construction	250,000
Japan	Ningyo-Toge Pilot & Demo	JAEA	Centrifuge	Shut down	250,000
	Rokkasho	JNFL	Centrifuge	Operating	150,000
				Planned	1,350,000
Netherlands	Almelo	Urenco	Centrifuge	Operating	3,800,000
				Planned	700,000
Pakistan	KRL Kahuta	PAEC	Centrifuge	Operating	15–20,000
	Unconfirmed plant, Kundian	PAEC	Centrifuge	Planned	Unknown
Russia	Urals ElectroChemical Combine—Novouralsk	Rosatom	Centrifuge	Operating	9,800,000
	Siberian Chemical Combine—Seversk	Rosatom	Centrifuge	Operating	2,800,000
	Zelenogorsk ElectroChemical Plant	Rosatom	Centrifuge	Operating	5,800,000
	Angarsk ElectroChemical Combine—International Uranium Enrichment Center	Rosatom	Centrifuge	Operating	2,600,000
	Uranium Enrichment Center—Angarsk	Rosatom/Kazatomprom	Centrifuge	Planned	5,000,000
South Africa	Z-Plant—Pelindaba	NECSA	Aerodynamic	Shut down/dismantled	300,000
	Y-Plant—Valendaba	NECSA	Aerodynamic	Shut down/dismantled	10,000
United Kingdom	Capenhurst	BNFL	Gaseous diffusion	Shut down	350,000
		Urenco	Centrifuge	Operating	5,000,000
United States	Oak Ridge GDP	U.S. DOE	Gaseous diffusion	Shut down	8,500,000
	Paducah	USEC	Gaseous diffusion	Operating	11,300,000
	Portsmouth	USEC	Gaseous diffusion	Standby	7,400,000
	National Enrichment Facility	Urenco	Centrifuge	Under construction	5,900,000
	Lead Cascade, Piketon	USEC	Centrifuge	Under construction	Pilot
	American Centrifuge Plant, Piketon	USEC	Centrifuge	Planned	3,800,000
	Eagle Rock Enrichment Facility	Areva	Centrifuge	Pre-licensing	3,300,000
	SILEX Test Loop, Wilmington	GLE	Laser	Under construction	Pilot
	GLE (SILEX) Plant, Wilmington	GLE	Laser	Pre-licensing	3.5–6,000,000

From: Laughter, M. (2009). *Profile of World Uranium Enrichment Programs - 2009 (ORNL/TM-2009/110).* Oak Ridge: Oak Ridge National Laboratory.

APPENDIX 3: AQUEOUS REPROCESSING PLANTS WORKING GROUP REPORT

INTRODUCTION

The IAEA currently conducts routine safeguards inspections at two reprocessing plants in Japan—the Tokai Reprocessing Plant (TRP)[1,2,3] and the Rokkasho Reprocessing Plant (RRP).[4,5,6] When these facilities are in full operation, the IAEA currently implements a continuous inspection approach. This approach can require up to 20% of the IAEA Safeguards Department's total inspection effort. The IAEA also carries out inspections on a limited basis at reprocessing plants in France (La Hague), the United Kingdom (THORP), and India (Prefre) when these facilities are handling spent fuel from specified sources (e.g., La Hague reprocesses spent fuel from reactors in Japan). A number of countries have announced plans for future construction of reprocessing plants. Japan may build another plant, which would be inspected under their INFCIRC/153 agreement. India may build a large scale reprocessing plant that could possibly be inspected by the IAEA under India's INFCIRC/66 agreement,[7] while the United States and China could offer future reprocessing plants for inspection under their Voluntary Offer Agreements (VOA). The IAEA also may be called on to implement verification approaches for reprocessing plants under disarmament treaties, such as the Fissile Material Cut-off Treaty (FMCT).[8]

If safeguards were implemented at the level currently applied in Japan, these expansions would require a dramatic increase in resource demand—well beyond current IAEA capabilities. The "first-line" effort to reducing these resource requirements, while increasing facility transparency, is designing safeguardability into the plant at the earliest possible time.

The objective of the Aqueous Reprocessing Plants Working Group was to discuss and collect recommendations that would aid in the coordination and integration of nuclear material accountancy with the domestic and international safeguards requirements of all concerned parties—owners/operators, State/regional authorities, and the IAEA. These recommendations, which will be provided to the IAEA, are intended to assist in optimizing facility design and operating parameters to ensure the safeguardability of the facility while minimizing impact on the operations. The one-day working group session addressed a wide range of design and operating topics, which can be generally categorized as follows:

- Physical design and its "verifiability"
- Facility nuclear materials accountancy measures
- Transparency of operations and operating procedures
- Accommodation of and accessibility to inspectors
- Plant administration and safeguards culture

This paper reports on the working group discussions and presents details on its proposed ideas and recommendations. *It should be noted that not all recommendations were accepted by consensus.* This report addresses those of the majority, while attempting to include the concerns of all participants.

WORKING GROUP OPENING AND PRESENTATIONS

Opening Statement: Mr. Mark Schanfein (Idaho National Laboratory)

Working group moderator Mr. Mark Schanfein opened the meeting by reviewing the working group's agenda, emphasizing the importance of a final draft document, and acknowledging that there could be some overlap with the other working groups.

"Safeguards by Design"—Some Thoughts by AREVA: Mr. Marius Stein (AREVA, Canberra)

In his presentation, Mr. Marius Stein of AREVA stated that Safeguards by Design is not new to AREVA and is already an integral part of its design and construction process. The IAEA Safeguards Approach needs to be established prior to the final design and start of construction in order to ensure that all systems are integrated and operational during commissioning. For a complex facility such as a reprocessing plant, it is extremely important to engage participants from the designer, owner, operations and regulatory oversight teams. A corporate investor will work with an architect/engineer, multiple construction contractors, and the owner/operator who will commission and operate the facility. Domestic and international safeguards should be considered starting at the concept design phase.

The primary basis for the implementation of international safeguards in reprocessing plants will continue to be the verification of the declared material flows, inventory, and facility operations as reported though the State/Regional System for Accountancy and Control (SSAC/RSAC) to the IAEA. Domestic safeguards will continue to provide assurance of the accuracy of those declarations. Due to the IAEA's limited resources, maintaining continuity of the dialog over the entire period of a long-term design and construction effort can be challenging for a complex facility (e.g., reprocessing). SBD requires a balanced approach with all stakeholders involved to ensure that safety, safeguards, and process controls are integrated, while recognizing a clear distinction between their functions with respect to responsibilities and access to data.

Mr. Stein's presentation focused on the need to define and improve the design requirements of the IAEA as early in the design process as possible and to verify that the inspectorates will have sufficient accessibility and flexibility to implement these requirements in the future. During the design stage of any nuclear facility, an integrated, life-of-plant approach is necessary to implement international safeguards-related requirements, optimize inspector access and activities, and facilitate the generation and handling of safeguards-relevant data while minimizing any adverse impact on normal operations.

Euratom Safeguards—Reprocessing: Mr. Peter Chare (Euratom, European Commission)

Mr. Chare's presentation discussed Euratom's implementation of safeguards in reprocessing plants in the United Kingdom (Sellafield/THORP) and France (La Hague). Euratom had found it necessary to revise its verification approach schemes because of the need to reduce human resource requirements. Euratom is now moving toward remote collection in which data are transferred to its Luxembourg headquarters for analysis.

The presentation included a review of typical plant operations and process equipment as well as process streams important to inspection activities. Since Euratom conceptualizes the process area as a "blackbox," it focuses monitoring activities on input and output measurements rather than the processes within. These are traditional accountancy measurements for flow verification, such as volume measurements combined with inspector samples. Weight measurements, made on solid-product materials, are usually complemented by containment and surveillance. Non-destructive assay (NDA) techniques are applied in product storage areas to confirm identity of packages as they enter and the quantity of plutonium (Pu) therein. A form of flow-sheet verification is applied for verification of operation as declared.

For the head-end and main process areas, the safeguards approach is based on material accountancy and evaluation of the material unaccounted for (MUF) at inventory closure periods. The audit of reported measurements relies on independent verification measurements. The Physical Inventory Verification (PIV), along with MUF and sigma-MUF evaluation, is conducted on an annual basis. The annual evaluation is complemented with monthly Interim Inventory Verifications (IIV). Containment and surveillance review of the storage areas is also important.

Designing and Operating Aqueous Reprocessing for "Safeguardability"—Some Considerations: Ms. Shirley Johnson (Tucker Creek Consulting)

Ms. Johnson's presentation introduced the working group's draft guidance document, "Draft Safeguards by Design for Aqueous Reprocessing Plants," and provided an overview of the topical areas to be discussed. The presentation also provided background information,[9,10] as well as explanations related to the design considerations in the draft guidance document.

WORKING GROUP DESIGN CONSIDERATIONS

The objective of the working group was to discuss and record recommended design considerations that could assist the IAEA in its development of guidance for facility owners/operators and designers. This guidance would aid in the coordination and integration of nuclear material accountancy with the safeguards requirements of all concerned parties: owner/operator/designers, State/regional authorities, and the IAEA. Optimization of the facility design and operating parameters would (1) enhance the "safeguardability" of a facility, and (2) improve the effectiveness and efficiency of safeguards implementation, on a schedule consistent with design, construction and commissioning of a reprocessing plant, and within the resource limitations of the owner/operator, State and IAEA. The recommendations of the working group covered various design and operating topics, including:

- Physical design and its "verifiability"
- Facility nuclear materials accountancy measures
- Transparency of operations and operating procedures
- Accommodation and accessibility for inspectors
- Plant administration and safeguards culture

Capabilities for and Ease of Design Examination and Verification

The IAEA's design information examination and verification begins with pre-construction activities and continues through construction, commissioning, operation, and shutdown/close-down until the facility has been verified as "decommissioned for safeguards purposes."[11] Guidance should recommend that safeguards-relevant design features be considered as early as possible in the design process. The preparation and official submittal of the Design Information Questionnaire (DIQ) by the operator/State does not take place early enough to provide an opportunity for the IAEA to participate in the design phase. Thus, the operator/State should provide informal design plans and information at a very early stage in the facility design process, which would be consistent with GOV/2554/Attachment 2/Rev.2 (1 April 1992).[12]

During the early life-cycle phases of a facility (i.e., pre-construction, construction and commissioning), the designer, owner/operator, State and the IAEA should be in close communication. A design team, including representatives from all concerned parties, should be established. An early activity of this team could be to identify synergies between safeguards, safety, security and criticality control requirements and then to address their impact on plant design. A mutual training program could also enhance understanding of each party's needs and concerns.

The provision of design information that has high commercial or proliferation sensitivity should be minimized. Design information that is sufficiently sensitive that it must remain in the control of the facility owner/operator should be identified early in the process. Arrangements for inspector access to the information must be established and agreed, such as storage of the information in an on-site operator-controlled area under both IAEA and State seals.

In areas of the plant that will have no future access (e.g., due to concrete pours) or limited access (e.g., enclosed trenches and process cells) after construction, design verification should be considered during the pre-construction and construction phases. Additionally, provisions should be made for the continuing design verification of selected "difficult to access" strategic cells. Remote viewing devices or access to the cells during maintenance periods would increase assurance that no changes are made to safeguards-relevant features. This may require innovative or improved verification tools for "difficult to access" locations (e.g., cells and pipes).

To better understand the design, operation, and measurement capabilities of the primary accountancy vessels (the Input and Output Accountability Tanks, IAT/OAT), selected high-inventory vessels, and difficult-to-measure vessels and equipment (evaporators and separators), the building of to-scale models at a demonstration facility is recommended prior to construction and installation in the plant. Demonstration vessels and equipment would allow optimization of internal structures for calibration, testing of homogenization capabilities, realization of environmental-control effects, and validation of the sampling system. For difficult-to-measure vessels, it would provide an opportunity to develop and verify inventory hold-up algorithms. Access to the demonstration/test facility would benefit not only the designer and operator, but also State and international authorities.

Consideration should be given to the IAEA's requirement for yearly or periodic recalibrations or calibration checks on selected inventory and inventory change vessels. The installation and use of permanent calibration systems, and standardized procedures during the initial calibrations of selected vessels, would afford more controlled and reproducible conditions during future calibration activities.

Because the IAEA must be aware of any maintenance or modifications to the plant design or operations that could impact safeguards implementation, the operator should make available to the State/IAEA an updated operational schedule on a continuing basis.

Design Considerations for Nuclear Materials Accountancy and Verification Systems

GENERAL DESIGN AND OPERATING FEATURES

The general design and operations should incorporate clear and identifiable boundaries that will assist in establishing Material Balance Areas (MBA), Inventory Key Measurement Points (IKMP), and Flow Key Measurement Points (FKMP). Therefore, it is important that the facility owner/operator, State and IAEA agree on the number and location of MBAs and KMPs early in the design process.

Plant operations can have a large impact on the ease and transparency of a Nuclear Materials Accountancy (NMA) system. Batch transfers between vessels within the process, where and when possible, facilitate the taking and verification of in-process inventory and inventory changes of an operating plant. Batch transfers also reduce the amount of inventory hold-up in piping and provide clearer boundaries for inventory measurements and declarations at the time of Interim Inventory Verification (IIV).

Plant operations and NMA should be designed to track nuclear material throughout the plant and be capable of providing inventory declarations on short notice. The facility NMA system should include effective measurement control procedures to rapidly assess and internally review and approve accountancy measurements for declarations to the State/regional authorities, who will transmit them to the IAEA. This will be of increased importance if the IAEA uses an electronic mailbox at reprocessing facilities in the future. Operator declarations may need to be provided in near real time to the IAEA or through the State authority (as agreed).

Unmeasureable inventory (UMI) in locations such as pipes, pumps, evaporators, and separators should be minimized, for example, by avoiding long distances between buildings with piping through non-accessible trenches. To minimize UMI, facilities should be compact and without excessive piping (where possible). Since a facility cannot completely avoid UMI, algorithms should be developed and tested which will quantitatively define it. Other considerations to address UMI include:

- Constructing scale-model tests to develop algorithms;
- Estimating hold-up from engineering designs;
- Testing and confirming UMI values during commissioning; and
- Designing in ways to allow pipes and pumps to drain and to establish the receiving MBA.

Design consideration also should be given to nuclear material rework and chemical recycle capabilities to assure that they are transparent, measurable, and available for verification. Misuse or undeclared use of these auxiliary processes is a safeguards concern. Therefore, access to these areas would increase confidence that the facility is being operated as declared.

Both liquid- and solid-waste handling and treatment areas should be clearly segregated and defined and should include a detailed waste-tracking and measurement system that documents the origin of all waste batches. This capability may be required for the operator to determine waste quantities for accountancy declarations and the implementation of IAEA verification procedures.

Inspectors may require short notice random access to agreed safeguards-relevant operating data, information, or equipment to increase assurance that a facility is being operated as declared. These access requirements should be established early so operating procedures, such as security and safety, can accommodate them.

OPERATOR NUCLEAR MATERIAL ACCOUNTANCY SYSTEM

The design of the NMA system should be considered in the facility's early design stages and be coordinated with the plant operations design as well as State authority and IAEA requirements. It should be capable of meeting domestic safeguards requirements and providing information to the State for submittal to the IAEA. NMA procedures should include appropriate measurement control activities and provide timely submittal of flow and inventory declarations, including relevant source data, to the State and the IAEA. The system should provide agreed operating information, such as operating status, schedules, and process disruptions.[13] Finally, the operator's NMA system should have near real-time access to operating and in-plant accounting data.

IAEA DATA COLLECTION AND EVALUATION SYSTEM

Inspector verification data should be securely transmitted from the various inspector-installed and unattended measurement, monitoring, and surveillance stations within the facility to a central database, possibly in the local inspector's office and/or to the IAEA headquarters or regional office. Therefore, IAEA data transmission requirements should be specified and considered in the design and construction of the plant. If off-site transmission of inspector verification data is anticipated to support short-notice or remote inspections, it should be negotiated early so that security considerations can be addressed. Additionally, the handling of operator proprietary information should be addressed during the design of the Data Collection and Evaluation (DC&E) system.

OPERATOR, STATE, AND IAEA DATA HANDLING SYSTEMS

Design specifications for the integration of the operator's NMA system and the inspector's DC&E systems should be included in the pre-construction phase as an integral part of the development of the Safeguards Approach, and of the design and operation of the facility.[14] Interface control documentation should be specified and agreed at an early stage. However, to prevent any threat of interference with plant operations or tampering of either system, physical connections between the inspector and operator data systems should be avoided where possible. Data transmission within the facility should be on a high-speed network (hardwired and/or wireless) connecting all safeguards-related equipment. Network connections should be installed in all areas of the facility to support future technologies. Data should include State of Health (SOH) information from all remote, unattended measurement and monitoring systems. In addition to data received from installed and unattended systems, the analytical results from accountancy and verification samples should be received in a timely manner from the relevant laboratories.

To reduce the human workload, the systems' software should be capable of doing reviews and extensive pre-evaluations of data in an automated and real-time mode. Pre-evaluations could include data quality checks, data correlations, consistency checks, and paired-data comparisons. The system should automatically call attention to possible data discrepancies, schedule changes, and completion of actions, and it should announce irregularities in the SOH. The system also should allow for interactive reviews and "drill-down" capabilities to facilitate operator and inspector reviews and investigation of possible discrepancies. Report-ready summaries and evaluations should be provided for various stages of the accounting and verification process.

Design Considerations for Measurement Systems

To reduce on-site inspector presence, unattended measurement and monitoring systems should be installed, where possible, for verification of operator declarations and assurance that the facility operations are as declared. Constraints may dictate that installed measurement systems should be jointly used by the IAEA and State and possibly the operator. All parties and the system developers should consult during the pre-construction phase. All joint-use systems should have security and/or authentication measures incorporated into their design. All IAEA systems, whether solely for IAEA use or joint-use, should have third-party vulnerability tests to verify their tamper resistance/detection and the validity of the acquired data. Particular attention should be given to both the State and IAEA requirements to reach independent conclusions.

The operator should implement measurement systems and a control program that confirms all accountancy data is in conformance with International Target Values (ITV)[15] and meets facility specifications. The measurement control program should provide timely information on the performance of measurement systems, including documentation of statistical performance.

The design and operations of the plant should be such that a minimum number of samples need to be taken at the time of the operator's inventory declaration and that the majority of inventory can be verified by in-vessel measurement systems,[16] sample taking, or process-design estimations. Moreover, continuity of knowledge of the flowing inventory should be maintained from the time of the inventory declaration to the time of the verification measurements.

During the pre-construction phase of a facility, the owner/operator, State, and IAEA should agree on the responsibilities for the design, procurement, installation, operations, and maintenance of inspectorate verification equipment.

The facility should include an uninterruptible power supply (UPS) for all safeguards-related equipment. Access to a UPS is recommended in all areas of the facility to support future technologies.

Design Considerations for Process Monitoring

The State and IAEA process monitoring (PM) systems, whether solely owned and operated or jointly used, should provide independent verification of the operator's declarations and assurance that the facility is being operated as declared. These systems may include solution monitoring for volume and density, or the monitoring of specific elements or process parameters.[17,18] Additionally, if the agreed IAEA safeguards approach includes the implementation of Near Real-Time Accountancy (NRTA), the approach would require the operator's accountancy and PM systems to be capable of providing almost-immediate inventory declarations based on the best available accountancy and process data. The IAEA may choose to use independent PM systems or jointly use the operator PM systems to meet its goals for verification of the operator's declaration and to maintain continuity of knowledge of the nuclear material flow.

Installed PM systems may require the capability of continuously monitoring the flow and storage of nuclear material from spent-fuel receipt and storage, through the head-end and separations process, to the back-end conversion process and storage. The facility design and safeguards approach should be considered simultaneously to establish the required equipment and locations of the PM systems.

The operator's PM systems should be designed and operated for the purpose of providing direct and timely information (and declarations) on the location and movements of nuclear material throughout the plant at any specified time. This would assist the operator's NMA office in preparing more accurate and timely inventory declarations.

The separation of alternative nuclear materials, such as neptunium, is monitored by the IAEA on a voluntary basis. The monitoring of neptunium using Flow Sheet Verification (FSV)[19] also provides added assurance that the process is being operated as declared and may be included in the IAEA safeguards approach. The FSV would require the operator to establish during active commissioning (and then declare) the expected flow sheet for that element throughout the process, including waste streams. Installed measurement systems may also be required.

Design Considerations for Sampling and Analytical Capabilities

Although installed unattended measurement systems would be the most desirable for providing accountancy and verification data, sample taking cannot be totally avoided. Sample taking is needed (1) to offset higher uncertainties associated with unattended measurement systems, (2) for authentication of those systems, (3) for use where on-line measurements are not possible, and (4) as part of a Quality Assurance/Quality Control (QA/QC) program. Installed sampling systems and their effects on the validity of the samples should therefore be considered during plant design. The design criteria should take into consideration such factors as evaporation, homogenization, and sampling depth, as well as the capability of sampling multiple vessels simultaneously. Operator sampling systems jointly used by the State and IAEA also should be designed to provide transparent operations, sample traceability, low tamper vulnerability with provisions for authentication, and high flexibility in the taking and scheduling of samples.

Early-design criteria should address IAEA usage and authentication requirements for a joint-use, operator-owned sampling system. The sample authentication system[20] and procedures that ensure the integrity of empty and full inspector sampling vials should be included. The sampling system should be capable of tracking the sample vials from their introduction into the system, transfer to the process sampling location, and return to inspector control with high assurance that a valid and true sample has been obtained.

Early design considerations also should consider whether an on-site laboratory will be built for IAEA use or joint-use with the State.[21,22] Although an on-site IAEA laboratory requires a large financial and human resource commitment, it provides the following benefits:

- For the inspector:
    - Improved control of inspector samples and reduced chance of tampering;
    - Timely analytical results of equal quality to those of the IAEA's network of analytical laboratories or International Target Values (ITV);

  - Ability to handle large sample aliquots, as compared to the dried samples sent to the IAEA Safeguards Analytical Laboratory (SAL) in Seibersdorf, Austria;
  - Ability to recycle waste back to the process; and
  - Reduction in the cost of shipping samples to the SAL.
- For the operator:
  - Reduction of resource requirements for preparation of inspector samples;
  - Significant reduction of paperwork required for shipping inspector samples to SAL; and
  - Reduction of operator responsibilities for handling inspector samples and chances of mishaps.

If a full-scale inspector laboratory is not required, other options could include use of the operator's laboratory for sample preparation and/or a limited selection and number of measurement systems. Use of the operator's laboratory and staff would require additional security and authentication measures for sample taking and measurements.

Design Considerations for System Security and Authentication

To conserve financial resources and taking into account limited physical space and access constraints in the plant, some measurement and monitoring systems may need to be installed and used jointly by the IAEA[23] and State inspectorates, and, in some instances, the operator.[24]

The following data security issues should be considered during design and installation of measurement or monitoring systems:

- Assurance that data has originated from a known source and has not been altered, removed, or substituted;
- Assurance that data from joint-use systems cannot be used in such a way as to influence the accountancy and operational declarations by the operator to the inspectors;
- Assurance that the State cannot use knowledge of the systems and data, in collaboration with the operator, to defeat the implementation of reliable IAEA safeguards measures and investigations into possible discrepancies; and
- For unattended systems, a level of assurance comparable with other safeguards measures. An appropriate standard of encryption should be employed to confirm that sensitive information has originated from a known source and has not been altered, removed, or substituted.

IAEA security and/or authentication needs and requirements should be identified early to enable their incorporation into facility design, operating procedures and/or equipment. A few current examples of security and/or authentication methods include:

- Installed technical methods:
  - Hardware: Tamper-indicating enclosures (TIE) or sealed tamper-indicating enclosures (STIE); seals; camera surveillance; safeguards conduit; and motion, heat, or radiation sensors
  - Software: IPsec; "sign and forward" (SnF); varying levels of password control; delayed data access for operator/State; and other methods of data encryption

- Procedural methods:
    - Portable cable testers, optical time domain reflectometers (OTDR), and portable pressure gauges
    - Cross-correlation of data from a number of sources, whether various sources for the same piece of data or related data from various sources (such as adjoining vessels)
    - Sealed standard containers and sealed sources
    - Short notice random sample taking for independent analyses
    - Short notice random visits by inspectors (observations or measurements)

Other Factors for Consideration

There are a number of other questions to consider when designing and operating a plant with the goal of enhancing its safeguardability, including the following:

- Where will the plant be located? What is its proximity to Vienna and the IAEA's SAL? What is the local availability of technical services?

- Will the plant safety and security arrangements be able to accommodate short- or no-notice random inspections?

- How can a safeguards culture be promoted and assured among the operating staff?

- What will be the expected educational and experience levels, and training requirements for the IAEA, operator and State safeguards staff?

SUMMARY OF CONCLUSIONS AND DESIGN CONSIDERATIONS

1. The working group focused on the implementation of IAEA safeguards rather than the State/Regional Systems of Accountancy and Control (SSAC/RSAC) safeguards requirements. This allowed the group to concentrate on more specific requirements, while keeping in mind that the results of the discussions could apply to other areas of safeguards regulation. The working group agreed that the current goal of Safeguards by Design (SBD) discussions is to establish guidelines and design considerations for plant designers and owners/operators. However, these discussions should not only facilitate understanding by designers and owner/operators of specific design concerns, but also the IAEA and SSAC/RSACs in their development of SBD guidelines. They should provide the basis for the IAEA and industry to find solutions.

2. There is a continuing need to improve the formality of the design process in order to enhance the SBD discussions among all concerned parties and to lead to a more efficient implementation of international safeguards. The SBD responsibilities particular to each party—designer, owner/operator, State, and IAEA—should be clarified. A description of the design activities conducted during the conceptual and preliminary steps also needs to be clarified.

3. SBD guidelines should avoid technical or design considerations tied to any particular current day technology or set of technologies that may not be relevant in the future. However, the development of new technologies should be carried out with the expectation that new technologies will exceed the current levels of sensitivity, unattended operations, reliability,

robustness, ease of trouble-shooting and maintenance, and relative costs. SBD guidelines should provide technological recommendations and prioritization of research and development (R&D) needs in the future, and should provide information that could assist designers and owner/operators in determining what technologies may be required to successfully improve the safeguardability of the facility.

4. Unlike other types of nuclear facilities that may have standardized designs and may be built in a number of different countries, new reprocessing plants are likely to be unique and customized for their host country. Therefore, SBD recommendations should account for the possibility of non-standardization.

5. Guidelines should recommend that safeguards-relevant design features and operating procedures are considered as early as possible in the design process. The preparation and official submittal of the Design Information Questionnaire (DIQ) by the operator/State does not presently take place early enough for the IAEA to participate in the design phase. Thus, there should be an informal provision of design plans and information at an early stage, in accordance with GOV/2554/Attachment 2/Rev.2 (1 April 1992):[25]

   "Parties to comprehensive safeguards agreements will need to provide design information to the Agency at the time of the decision to construct, or to authorize the construction of, any nuclear facility (i.e., well before construction actually begins) in order to create confidence in the peaceful purpose of the facility and to provide adequate lead-time for safeguards preparations - more specifically:

   (a) to facilitate the incorporation into the facility design - including the design of the nuclear materials accountancy system - of features which will make it easier to implement safeguards at the facility (any proposed design modifications being consistent with the prudent management practices required for the economic and safe operation of the facility and such as to avoid hampering or delaying construction, commissioning or operation);

   (b) to allow time for safeguards research and development work that may be necessary;

   (c) to enable the Agency to do the budgetary planning necessary for the effective and efficient implementation of safeguards; and

   (d) to permit the identification and scheduling of actions which need to be taken jointly by the State, the facility operator and the Agency, including

      i. the installation of safeguards equipment during construction of the facility; and

      ii. the verification of information on the design of the facility."

6. The IAEA should respond to the operator's early provision of design information with a conceptual safeguards approach to ensure a successful process.

7. The minimization of the quantity of un-measureable inventory (UMI) should be included as a design priority for reprocessing plants. Because UMI cannot be eliminated, early testing should be conducted to establish proven and verifiable algorithms that may be used for operator inventory declarations and inspector verification purposes.

8. During the design phase, on-site analytical capabilities, whether destructive analysis (DA) or non-destructive assay (NDA), should be considered for IAEA use. These capabilities could include (1)

the introduction of an independent inspector laboratory, (2) installation of unattended measurement and monitoring systems, and/or (3) joint-use of State or operator facilities and equipment. Early cost-benefit evaluations should compare inspector presence for the purpose of carrying out measurements versus the use of complex unattended systems.

9. From an SBD perspective, maximizing joint-use equipment is desirable. The advantages and disadvantages of joint-use equipment should be assessed prior to construction, giving particular attention to the system security and authentication required by the IAEA to reach independent conclusions.

10. The large and growing volume of safeguards data that will be produced at reprocessing facilities will increase the need to automate such activities as data generation, pre-evaluation, reporting, authentication, and encryption. Due to the size and complexity of these data management systems, their requirements should be incorporated into the overall plant design. Data transmission within the facility (and possibly off-site) also should be considered, which will require early negotiations on security issues.

11. The design team should include the owner/operator, designer, State, and IAEA. A possible recommendation would be that the IAEA draw temporary staff from the owner/operator design team. Moreover, the design team should make an effort to hire some staff with safeguards background or expertise, which could enhance communication between the parties.

12. The IAEA should consider a training course for design organizations (those that are considering designing and/or building plants or have contracts to do so), which would provide an understanding of safeguards and the elements of plant design that may have an impact in implementing effective and efficient safeguards. The IAEA also should consider ways to keep designers abreast of new and modified safeguards requirements.

13. There are many synergies between the SBD and requirements for safety, security, and criticality control. Although plant designers have regular contact with the IAEA's Department of Nuclear Energy and Nuclear Safety, there is little contact with the Department of Safeguards. The Safeguards Department should consult with these other departments to determine where they can collaborate to avoid duplication.

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APPENDIX 4: MOX FUEL FABRICATION FACILITIES WORKING GROUP REPORT

INTRODUCTION

Mixed oxide (MOX) fuel is made from a blend of plutonium and uranium oxide powders and can be burned in fast neutron reactors or in limited quantities in light water reactors (LWRs). France, the United Kingdom, Japan, the United States, and Russia are currently pursuing MOX fuel fabrication. Additionally, India has built an industrial-scale MOX fuel fabrication facility (MFFF) at Tarapur[1,2] and China is considering the construction of several MFFFs.[3,4] Additional details on the status of MOX fuel fabrication facilities worldwide can be found in the Appendix 4 Attachment.

The goal of the MOX Fuel Fabrication Facility Working Group was to share ideas on Safeguards by Design (SBD) concepts related to best practices, advanced technologies, and design features that can aid in effective and efficient implementation of IAEA safeguards at MFFFs. Related secondary objectives were to consider Euratom, IAEA, and State safeguards requirements, and also to discuss ways to minimize their impact on facility operations. This report summarizes the key points of the Working Group's discussions and outlines some of the most substantive ideas for applying SBD at MFFFs.

OPENING REMARKS AND PRESENTATIONS

Dr. Trond Bjornard opened the session by providing information on the roles and responsibilities of the working group members and by suggesting key points to consider during the discussions. Industry presentations describing experience with the application of SBD to MFFF, from AREVA and Japan Nuclear Fuel Limited, also provided a foundation for the working group discussions. Brief summaries of the presentations follow.

Euratom's 'Security Control during Construction' Approach at AREVA's MELOX Facility: Dr. Michael McMahon and Mr. Pascal Jaunet (AREVA)

AREVA's MELOX MFFF began operation in the South of France in 1995 for the fabrication of MOX fuel for both boiling water reactors (BWRs) and pressurized water reactors (PWRs). MELOX falls under French and Euratom regulations for European security control, which includes material protection, control, and accounting (MPC&A). During the construction and commissioning phases, MELOX was the focus of a collaborative effort between the operator, the State, and the European Commission for the development and implementation of security control. As described by Dr. McMahon, MELOX is a modern facility that has a number of technical characteristics to facilitate the application of security control. These technical characteristics include a high degree of automation, confinement of nuclear materials (NM) in gloveboxes, short residence time of NM in process equipment, and a combination of process control and product specifications that require accurate accountancy, frequent process monitoring and rigorous quality control.

Furthermore, development of security control for MELOX included the requirement for continuous operations without interruptions for safeguards verification. The early and continuous involvement of Euratom during construction permitted the development of an efficient and cost-effective security control approach that utilized existing operator equipment and production information. AREVA characterized the result of the "safeguards during construction" approach as a "win-win" scheme for all parties – ultimately all of Euratom's objectives were met without hindering facility productivity or affecting operator health or safety requirements.

Safeguards by Design in J-MOX, Experience and Findings: Mr. Kazuhiko Hiruta (JNFL)

Mr. Hiruta presented lessons learned from the incorporation of safeguards at the Japanese MOX Fuel Fabrication Plant (JMOX) and provided several recommendations for future facilities. The effort at JMOX was organized in phases including conceptual design, basic design, detailed design, manufacturing design, and construction. Although the Japan-IAEA Safeguards agreement did not mandate early discussions on SBD, JNFL took "preparatory measures to address future IAEA safeguards application" from the early design phase. This proactive approach, while less efficient than full and early engagement with the IAEA, was necessary to advance the facility design without the benefit of IAEA input at the early project stage. The Japan-IAEA discussion of the safeguards approach first began in 2005, about halfway through the detailed design phase, and continues into the construction phase today. The preparatory measures introduced by JNFL included consideration of accountancy instrumentation, nondestructive assay (NDA) equipment (with the help of input from Los Alamos National Laboratory), and containment and surveillance measures (C/S).

Mr. Hiruta noted that at the beginning of the design phase, detailed requirements for IAEA safeguards were not available. Mr. Hiruta suggested this as an area requiring future improvement, while noting that a number of preparatory measures are being revisited in ongoing discussions with the IAEA. Mr. Hiruta made the observation that if JNFL's preparatory measures partially achieved the objectives of SBD, then this approach could be applied in the design of future MFFFs.

PRIMARY CHARACTERISTICS OF MOX FUEL FABRICATION FACILITIES

MOX fuel fabrication typically involves high-throughput, bulk-handling facilities with a high degree of automation. In MFFFs, nuclear material (NM) is not readily accessible because it is in gloveboxes or fuel pins, and the NM has a short residence time in process equipment. NM verification is achieved by determining the net weight and isotopic composition of powder in cans and then electronically tracking each can. Powder composition is measured by destructive chemical assay at select locations in the process line.

For existing facilities, the MOX operation starts with either mixed PuO_2-UO_2 as feed, which additional UO_2 is added, or as separate PuO_2 and UO_2 powder streams. The fuel fabrication process begins by batching, blending, and milling the powders to achieve the correct composition (uranium to plutonium ratio), particle size and distribution, and particle morphology (or surface texture). The powder is transferred between process stations in reusable cans. After achieving the desired composition and particle characteristics, the powder is pressed into pellets that are sintered in a furnace. The pellets are then transferred between stations in trays (sintering boats); the NM is tracked and weights are recorded for material control and accounting. The loading of pellets into fuel pins changes the status of nuclear material accounting from bulk material to item control, which uses weight measurements and bar code scanning of loaded fuel pins. Finally, the pins are combined into fuel assemblies that are stored in a dedicated storage area. The tracking of nuclear material is henceforth accomplished using bar codes on the finished fuel assemblies.

Undeclared activities in a MFFF might include diversion of material, undeclared separation of Pu from U with subsequent conversion to metal, processing of undeclared materials at the facility, use of gloveboxes to handle undeclared material, and production of uranium targets. The working group consensus was that it would be difficult to conceal undeclared operations at a MFFF, since this would require additional equipment (such as dissolvers or metal furnaces) that would be easy to detect during design information verification (DIV) inspections.

SAFEGUARDS BY DESIGN CONSIDERATIONS FOR MOX FUEL FABRICATION FACILITIES

The primary goal of the MOX Fuel Fabrication Facility Working Group was to share ideas on SBD concepts related to best practices, advanced technology, and design features that can aid in effective and efficient implementation of IAEA safeguards at MFFFs. Related objectives were to consider Euratom, IAEA and State requirements, and to discuss ways to minimize their impact on facility operations.

The working group's most significant observations and ideas for SBD related to MOX fuel fabrication include the following:

- Based on experience with existing facilities, the application of safeguards to conventional (pellet-form) MFFFs should be relatively straightforward. This is not necessarily true for non-conventional fuel forms such as vibro-packed fuel and sol-gel (which were outside the scope of the working group's discussion).

    - Equipment should be designed to minimize holdup and material unaccounted for (MUF). The basic nature of fuel fabrication involves handling of powder and the consequent potential for formation of dust; collection of these materials in unwanted locations within the glove boxes increases MUF, which can often be mitigated with design choices (e.g., rounding the corners of gloveboxes).

    - Process control instrumentation can be used for NM accountancy. Criticality control requires knowledge of the amount and precise location of NM. As a result, equipment and instrumentation related to criticality control can serve as the basis for an operator's system of accounting and control of NM. Accountancy, however, should not interfere with safety.

    - A MOX fuel fabrication process line includes locations for collecting NM prior to the next process step. If NM only flows through these collection locations in one direction, the locations can provide access and opportunities for independent IAEA measurements and application of C/S measures.

- Early engagement between the facility operator, facility designer, and the IAEA (or Euratom) is critical for SBD.

    - Safeguards objectives and/or criteria must be identified at the earliest possible stage.

        - Agency preparation of a model safeguards approach for a MFFF would provide the operator/vendor early insight for objectives, requirements, and/or criteria for safeguards.

    - There is a need for early voluntary dialogue between facility designer, operators, and the IAEA so that each party understands the others' requirements. Safeguards requirements should be taken into account during the design process of a MFFF, from initial planning through design, construction, operation, and decommissioning. International safeguards objectives would then be given similar importance as national safety and security requirements.

  - IAEA safeguards equipment and instrumentation are identified by the Agency, not the operator. The development of safeguards equipment in the facility design typically begins before consultations with the IAEA. Therefore, to support the application of SBD to MFFFs, consultations between operators/designers and the Agency should begin earlier in the design phase.

  - The State System of Accounting and Control (SSAC) and the IAEA should make a concerted effort to develop a specific list of data needed for NM verification in a MFFF based on a model safeguards approach. This list should include the NDA instrumentation and C/S equipment in current facilities and their requisite specifications. Potential modifications to the list, or to NDA and C/S technologies, should be discussed and agreed upon by all stakeholders, if possible.

- Standardizing typical safeguards equipment for each verification purpose would help to control costs. When installing the equipment in a specific facility, some modifications may be required to make implementation of the equipment efficient and cost effective.

  - Standardized safeguards equipment should be put in an open catalogue so that designers can access the information. However, it is recognized that since MFFFs are unique, making such a catalogue will be more difficult than for nuclear power reactors.

  - Preference should be given to equipment that is easily authenticated and able to provide two or more data feeds.

- Operator/designer provision of design information to the IAEA should begin at the inception of the facility and continues through design, construction, operation, and decommissioning.

  - To improve the IAEA Design Information Examination (DIE) session, the IAEA should first identify the fundamental documents it will require (such as a detailed design, a facility/equipment arrangement, a process/mechanical flow diagram, and operational procedures).

  - A transparent design can facilitate recurring DIV inspections.

  - Special agreements may be required for the use of proprietary and/or sensitive design information. Many times the design information (particularly security sensitive) is stored in an IAEA-sealed safe located onsite.

- Discussions concerning the nature, format, and timing of online data provided to the IAEA may in some cases continue even during commissioning, which can pose a set of challenges to the designer and operator.

- It is difficult for the operator to satisfy requests for additional online data (e.g., process control data) once the design is complete.
    - Requests for additional online data after the design is complete should wait until the next upgrade or replacement of the operator's computer system.
- Changes to a Material Balance Area (MBA) or to a Key Measurement Point (KMP) may require a significant modification of the operator's computerized accounting system.

- Joint use of process monitoring and other safeguards equipment by the IAEA and operator has both benefits and disadvantages. It requires early IAEA involvement in the facility and equipment design. On the other hand, the operator may not be able to accept joint-use equipment without sacrificing reliability and operability, and the State may raise security concerns.
    - Because of these factors, installation of independent IAEA equipment is often less complicated and mutually beneficial.
        - IAEA requirements for data authentication are highly specialized and can lead to expensive modification of operator's equipment.
        - The inclusion of space and infrastructure for safeguards equipment from the beginning would be more efficient and effective than retrofitting because the necessary provisions can be incorporated during the early design phase.
    - In some cases, joint-use equipment is the only solution because the process layout cannot accommodate additional safeguards equipment.
        - Even though all data must be independently verified, which can be difficult, the use of joint equipment can be advantageous for the IAEA because it may reduce the IAEA's equipment cost.

SBD DISCUSSIONS FOR MOX FUEL FABRICATION FACILITIES

The following sections provide additional observations and ideas for SBD related to MFFFs that were identified during the workshop.

IAEA MOX Fuel Fabrication Facility Verification Requirements and Inspection Efforts

- As a consequence of its timeliness goals for direct use NM, the IAEA must verify inventories at MFFFs on a monthly basis using an Interim Inventory Verification (IIV). Once a year, the operator performs a facility Physical Inventory Verification (PIV),[5] which occurs after the facility cleanout and NM characterization is complete. The IAEA then verifies the operator's PIV.

- Considering the MFFF inventories, the number of significant quantities (SQ) involved, and the timeliness goals for direct use NM, the IAEA should develop a standard safeguards approach for safeguarding future MFFFs used to fabricate standard pellet-form fuel. This generic approach, which would allow the Agency to capitalize on experience gained in safeguarding the MFFFs to date could include a reduction in inspection effort that does not compromise key safeguards technical objectives. This would be consistent with the IAEA's efforts to implement safeguards that are more fully information-driven.

- The IAEA should implement remote inspections along with short-notice or unannounced inspections on MFFFs. Short-notice or unannounced inspections should be accommodated by the facility design, operations, and entrance procedures. A cost-effective way of meeting these challenges in a MFFF is to emphasize the use of NDA equipment and containment and surveillance (C/S) measures, which would minimize the intrusiveness of IAEA safeguards in daily facility operations.

- Effective and efficient MFFF safeguards require the use of process monitoring in facility gloveboxes and assembly lines. Incorporating authenticated NDA measurements and C/S data features into a facility's design can allow for less interruptions to the operator while allowing the IAEA to draw an independent safeguards conclusion on verified NM flows and inventories.

Nuclear Material Accountancy

- In a modern MFFF there is a high degree of NM accountancy due to criticality concerns. NM accountancy systems and safety systems, however, should not be combined to the detriment of one or the other. It is also worth noting that while criticality and accountancy systems may share data, the full set of requirements for each often differ.

- The operator, State, and the IAEA have a common need to know the location of NM at any point in time. Near Real-Time Accountancy (NRTA) may play an even greater role in future MFFFs when considering the large throughput and possible material diversion scenarios in the facility. However, the IAEA and the State must agree on mechanisms and procedures for data sharing and transmission. NRTA methods and data sharing need to be communicated to the designer and operator as early as possible for inclusion in the facility design.

- Designing to minimize MUF is an important consideration. To address MUF, the IAEA may need to install independent process monitoring equipment. The physical footprint and requisite infrastructure (e.g., utility lines or data communication ports) of the equipment will need to be accommodated by the design. Minimizing NM holdup is another important design objective, as this can be a large contributor to MUF.

- The IAEA requires notification when NM crosses the boundary of a Material Balance Area (MBA). Therefore, having fewer MBAs reduces the impact on facility operations. However, operators typically subdivide MBAs for easier tracking of NM. Data from the sub-MBAs is rolled-up, and reported to the IAEA on the MBA level. Designers will need to think about changes in NM form (e.g., powder to pellets to fuel pins), especially when employing NRTA, as the accounting changes from bulk to item accounting.

- The design of an MFFF will need weighing systems that support NM accountancy. To meet the IAEA's needs, these systems should operate in unattended mode and should provide inspectors with independent verification. The IAEA requires dedicated gloveboxes for destructive analysis and NDA equipment, along with a means of processing samples for shipment offsite and must have space for storage of measurement standards and reference materials. These IAEA gloveboxes must be separate from the operator's system, and need the capability to be sealed. Safeguards NDA equipment should be integrated into the process equipment in order to avoid undue interference in the operation of the facility. A means for sampling items in automated facilities will need to be addressed. The facility design should minimize the number of samples that need to be shipped offsite. The design must include the infrastructure to support the sampling equipment, must accommodate NDA equipment servicing and allow for frequent data transmission.

- Additional measures beyond material accountancy to enhance safeguards, such as the use of containment, process monitoring, and radiological barriers, also will be important considerations for future MFFFs.

Containment and Surveillance (C/S)

- When developing a C/S system for future MFFFs, designers should:

    - Design to avoid the need to break C/S seals frequently;
    - Build the necessary infrastructure for frequent data transmission of C/S information;
    - Consider access to C/S for maintenance in the design phase;
    - Segregate the maintenance areas;
    - Design neutron monitors and surveillance cameras for a certain amount of redundancy;
    - Design for monitors, surveillance cameras, and seals that complement each other;
    - Ensure that dedicated support platforms for installation and maintenance are available; and
    - Provide continuous lighting, even when the facility is not operating due to maintenance shutdown, or a reduced shift schedule.

- A dual C/S system with two independent components would help maintain Continuity of Knowledge (CoK). A single C/S system has only one component to cover each plausible diversion path (e.g., a camera system or a type of seal applied to a container). In a dual system there are two independent components with two different failure modes that cover a plausible diversion path, such as one electronic and one metal seal. Even if there is a failure in one of the components, the second component will still allow for a positive conclusion.

- Sealing processing areas should be avoided. Breaking a seal requires inspector notification, and inspectors need to monitor seals, so the use of other means for processing areas such as neutron measurements or surveillance cameras to avoid the use of seals should be considered. However, using seals, neutron monitors, and surveillance cameras can reduce verification requirements. Using IAEA seals on IAEA equipment as well as the operator's NM containers and equipment can help to ensure authenticity.

Designing for Data Collection and Transfer

- Design features that facilitate remote inspections also will help to reduce the frequency of inspector visits, which would decrease both the operators' and Agency's costs. It is important to consider unattended systems for NRTA, NDA, and other similar monitoring techniques to reduce the number of IAEA inspection days. NDA and C/S measures presently installed and used at a MFFF should be considered as a possible selection for the first generation of remote inspection equipment. Remote monitoring may require that data be transmitted over installed fiber optic cabling.

- Utilizing state-of-health (SOH) updates from facility equipment can be less troublesome for the operator than sharing raw data. If there are sensitivities or security issues concerning certain information being sent off site, a red light/green light (alert/normal operation) method for possible problem notification could be utilized instead of sending the raw data to the IAEA; however, not all operators are in agreement with this solution. Operators may be hesitant to send a large volume of data to the IAEA.

- Cyber security is a challenge that will become increasingly severe with time and requires proactive design considerations. IAEA and operator networks should be kept separate. Discussions need to begin early in order to mitigate the threat posed by viruses and other internet-based external threats.

Continuity of Knowledge

- Establishing an easy and reliable method to maintain CoK between the fuel assembly at the MFFF and the reactor facility is desirable. The common goal is to minimize the need for re-verification of the fuel assembly at the reactor.

New Technologies & Inspections

- New technology can result in many challenges, such as attempting to network "intelligent" cameras by linking them between the inspector's network and the operator's network. Such issues may require installing separate equipment for each party, such as two sets of cameras. Sometimes the design solution can take considerable time, and does not always work as originally planned.

- Random Interim Inspection (RII), where the operator may need to transport NM to a measurement point, could disrupt operation. Short Notice Random Inspections (SNRIs) should be minimally intrusive and only agreed strata at different KMPs would be verified. This scheme will be a trade-off relative to the present approach, including frequent Interim Inventory Verifications (IIVs). The State and operator should understand that SNRIs are beneficial to facility operations and help facilitate cost-effective safeguards.

Tools Supporting SBD for MOX Fuel Fabrication Facilities

- Modeling and simulation of a MFFF would be useful to develop the safeguards approach. In addition to modeling the facility, the designers and operators should look at modeling measurement equipment and its effects on the safeguards approach. To accomplish this, designers could consider 3D virtual modeling. Specific areas that could benefit from modeling and simulation would be NM accountancy, C/S, positioning of surveillance cameras, installation of neutron monitors, and optimization of detectors for diversion.

SUMMARY

It was the consensus of the MFFF working group, based on members' collective experience with existing facilities, that application of safeguards to conventional (pellet-form) MFFFs should be relatively straightforward. This is not necessarily true for non-conventional fuel forms such as vibro-packed fuel and sol-gel (which were outside the scope of the working group's discussion). While SBD was efficiently and effectively implemented for MELOX due to early designer/AREVA engagement with French and Euratom regulatory representatives, this was not the case for JNFL's JMOX. International safeguards design for JMOX was, and continues to be, dictated by the IAEA/Japan Safeguards Agreement. This agreement does not mandate early engagement for the designer and IAEA. However, JNFL did implement limited SBD to the extent possible without full IAEA participation. This limited implementation of SBD was achieved through JNFL's willingness to assume considerable financial risk for the design by assuming relatively detailed IAEA safeguards objectives. The SBD considerations for MFFFs discussed during the NGS3 workshop and recorded in this document are based on the experiences of designers, inspectors and government representatives.

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NOTES

[1] Kumar, Arun, “Fuel Cycle Activities in India,” given at the INPRO Dialogue Forum on Nuclear Energy Innovations, 4-7 October 2010, International Atomic Energy Agency, Vienna, Austria.

[2] “India Opens New Reprocessing Facility,” World Nuclear News, 07 January 2011.

[3] “China’s Nuclear Fuel Cycle” updated February 2011 in World Nuclear Association, (available URL: http://www.world-nuclear.org/info/inf63b_china_nuclearfulecycle.html), accessed March 8, 2011.

[4] “MOX facility and Myrrha in Sino-Belgian deals,” World Nuclear News, 07 October 2010.

[5] IAEA Safeguards Manual, SMC 6, “Fabrication Plants Handling Direct-Use Material (MOX, HEU), International Atomic Energy Agency, Issued October 1, 2003.

APPENDIX 4 – ATTACHMENT: STATUS OF MOX FUEL FABRICATION FACILITIES

- Construction of AREVA's MELOX facility was completed in 1995 near Avignon, **France**. By 1997, MELOX was producing fuel at its licensed capacity of 100 metric tons of heavy metal (MTHM) MOX fuel per year. In 2007, the French government authorized AREVA to increase the production at MELOX to 195 MTHM/yr. European security control at MELOX is the responsibility of the European Atomic Energy Community (Euratom), with the exception of MOX fuel destined for Non-Nuclear Weapons States (NNWS), for which IAEA safeguards begin at shipment.

- In the **United Kingdom**, construction of the Sellafield MOX Plant (SMP) near the village of Seascale was completed in 1997. The current authorization for SMP is 40 MTHM/yr. In 2005, the United Kingdom's Nuclear Decommissioning Authority became the owner of SMP. Currently, SMP is operated by Sellafield Ltd., a wholly-owned subsidiary of Nuclear Management Partners (NMP), comprised of United Research Services (URS) of the United States, AMEC Ltd. of the UK, and AREVA of France. The international safeguards arrangement at SMP, as for MELOX, involves Euratom inspections with IAEA safeguards on any exports to NNWS.

- In **Japan**, the Tokai Plutonium Fuel Fabrication Facility (PFFF) currently produces approximately 10 MTHM/yr MOX,[1] while the Rokkasho MOX Fuel Fabrication Facility (often referred to as the JMOX facility) has been designed for 130 MTHM/yr.[2] The JMOX facility is currently under construction with operation tentatively planned for 2016. The PFFF is currently under IAEA safeguards, and JMOX also will be under IAEA safeguards once it becomes operational. PFFF is owned and operated by the Japan Atomic Energy Agency (JAEA), and serves primarily as a research and development facility. Japan Nuclear Fuel Limited (JNFL) owns and will operate JMOX as a commercial facility for MOX fuel fabrication.

- In 2000, the **United States** and Russia signed the Plutonium Management and Disposition Agreement (PMDA)[3] in which each country committed to dispose of no less than 34 metric tons of weapons-grade plutonium designated as surplus to defense needs. To implement its commitment under the PMDA, the Department of Energy is funding the construction of a MOX Fuel Fabrication Facility at the Savannah River Site near Aiken, South Carolina. This MFFF will have the capability to process 3.5 metric tons of surplus weapons-grade plutonium into MOX fuel per year. The U.S. MFFF is scheduled to begin operations in 2016. Shaw AREVA MOX Services, LLC is the prime contractor for design, construction, and startup of the U.S. MFFF.[4] If in agreement, the IAEA will participate in a Trilateral Initiative with the United States and Russia to jointly develop detailed monitoring and inspection procedures.

- In fulfillment of the PMDA, **Russia** may choose to burn MOX fuel in the existing BN-600 fast neutron reactor and/or the BN-800 fast neutron reactor now under construction, both located at the Beloyarsk Nuclear Power Station in Zarechny, Sverdlovsk Oblast, Russia.[5] To provide these reactors with MOX fuel, Russia also plans to build a MOX fuel fabrication facility.

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[1] JAEA Tokai (PFFF-ATR) in NFCIS Facility Report, (available URL: http://www-nfcis.iaea.org/NFCIS/NFCISMain.asp?Country=All&Status=In%20operation&Scale=Pilot%20facility&Ty

pe=SFRR&DetailedType=&Order=1&WhichFacility=240&RPage=1&Page=1&FacilityName=JAEA%20Tokai%20%28PFFF-ATR%29&RightP=Facility) accessed March 3, 2011.

[2] Rokkasho MOX Fuel Fabrication Facility in NFCIS Facility Report (available URL: http://www-nfcis.iaea.org/NFCIS/NFCISMain.asp?Country=All&Status=Planned&Scale=Commercial&Type=SFRR&DetailedType=&Order=1&WhichFacility=787&RPage=1&Page=1&FacilityName=Rokkasho%20MOX%20Fuel%20Fabrication%20Facility&RightP=Facility) accessed March 3, 2011.

[3]Agreement Between the Government of the United States of America and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (2000).

[4] "About the MOX Project," in *MOX Fuel Fabrication Facility* (available URL: http://www.moxproject.com/about/) February 2011.

[5] Russia and USA confirm plutonium plan, World Nuclear News, (available URL: http://www.world-nuclear-news.org/newsarticle.aspx?id=14428), November 20, 2007.

APPENDIX 5: GEN III AND GEN IV REACTORS WORKING GROUP REPORT

INTRODUCTION

This report summarizes the discussion and presents the conclusions and recommendations from the Reactor Working Group. The stated objective of the working group was to compile a collection of design-related suggestions and recommendations for practical application of Safeguards by Design in reactor facilities focusing on current (Gen-III/III+) designs, and generic reactor features applicable to future (Gen-IV) reactors.

According to the IAEA database there are 442 nuclear power plants units in operation worldwide, and 65 nuclear power plant units under construction, as of January 2011.[1] Roughly half of these are in Non-Nuclear Weapons States (NNWS), as defined in the Nuclear Nonproliferation Treaty (NPT), and will be subject to IAEA safeguards. In addition, many countries have recently announced plans to construct additional nuclear power plants within the next 5 to 10 years. This underscores the importance of implementing Safeguards by Design (SBD) for new reactor facilities.

FUNDAMENTAL POINTS OF DISCUSSION

The working group's discussion ranged from first principles and IAEA safeguards objectives to current and future reactor designs and specific issues regarding the implementation of IAEA Safeguards measures. To help focus the discussion, a background presentation regarding SBD as envisioned for light water reactors (LWRs) was given by Paul Pan of Los Alamos National Laboratory. [2, 3] The following points were stressed at the outset because of their fundamental importance:

The IAEA Has a Leadership Role in Promoting SBD

- Working group participants recognized and acknowledged that the IAEA must lead the effort to effectively and efficiently implement SBD in current (Gen-III and III+) and future generations (Gen-IV) of nuclear reactors and power plants. Specifically, the IAEA must articulate the relevant safeguards requirements and provide guidance through the State regulator/SSAC to the commercial nuclear industry on how best to implement these requirements. Recommendations from this working group are intended to help the IAEA formulate this guidance to the commercial nuclear industry.

Generation-III and III+ Reactor and Plant Designs Are Relatively Mature

- Industry representatives indicated that there is not a great deal of latitude for accommodating changes to the majority of current reactor designs. However, the designs of the Small Modular Reactors (SMRs), High Temperature Gas Reactors (HTGRs), and Gen-IV reactors in general are still evolving. Consequently, there is an even greater opportunity to incorporate and standardize safeguards features into this latter group of designs.

- Former IAEA inspectors noted that the current safeguards approach for most nuclear power plants depends on proven containment and surveillance systems (e.g., seals and digital surveillance camera systems), and nuclear material accounting measures, which have been implemented by the IAEA for decades at over 200 nuclear power plants worldwide. Most working group participants do not expect any serious challenges with implementing established safeguards measures in the Gen-III and III+ reactor designs.

The Need for the Application of IAEA Safeguards in Nuclear-Weapons States is Questionable

- Some participants expressed the view that safeguards implementation in NPT Nuclear Weapons States (NWS) is irrelevant and a waste of time and resources.

- Other participants noted that even in the case of NWS, the IAEA still has the right, under Voluntary Offer Safeguards Agreements (VOA), to inspect nuclear facilities selected from the country's Eligible Facility List (EFL), which includes most civil nuclear facilities in the country.[4] Some participants added that if U.S. nuclear reactors or technology are exported to NNWS, those states have a legal obligation to put their nuclear reactors under IAEA safeguards. Safeguards by Design could help to limit project risk in such cases.

SUMMARY OF REACTOR WORKING GROUP DISCUSSION

The diverse set of working group participants included national and international governmental officials, representatives from the IAEA, former IAEA inspectors, nuclear safeguards consultants, nuclear safeguards specialists and scientists from U.S. National Laboratories, and representatives from the international commercial nuclear industry. Consequently, they held differing views on how best to implement SBD for new nuclear power plants. While most conclusions were endorsed by the majority of the working group, minority views are also included in this report. The following includes a summary of the key points made during the working group's discussion.

Operator's Concerns

The designs of Gen-III and Gen-III+ reactors are mature. There is little latitude for the introduction of significant design changes to accommodate international safeguards. However, there is scope for SBD considerations for Small Modular Reactor (SMR) and Gen-IV reactors (such as the Pebble Bed Modular Reactor, PBMR). Interim Spent Fuel Storage Installations (ISFSIs), which typically include a dry storage facility on the nuclear power plant site, could also benefit from SBD. Since ISFSIs are increasingly implemented at nuclear power plants, they need to be considered in the overall safeguards approach for a given reactor site. Industry should therefore be aware of the relevant safeguards requirements and, where possible, accommodate them with facility designs. The working group recommends the creation of a mechanism for updating and implementing the latest safeguards requirements at operating nuclear power plants, and for those undergoing the construction and operating licensing process. As envisioned by the working group, the IAEA could prepare updated Guidance Documents that describe the safeguards requirements and best practices for implementing the requirements for reactors of a particular design (i.e., Pre Gen-III, Gen-III/II+ LWRs, On-Load Refueled Reactors (e.g., CANDU), Gas Cooled Reactors, etc.). Implementation of the requirements would be addressed by the State Regulator/SSAC through the updating and enforcement of relevant national regulations.

Sensitive Information and Joint-Use of Plant Equipment

Members of the working group expressed concern regarding the need to protect the facility operator's and designer's data, which may be sensitive in terms of nuclear technology, commercial value, or both.

Such data is often handled by the IAEA during the examination and verification of facility design information (DIE/DIV). While IAEA procedures exist to protect design information, and the handling thereof, the handling of commercially sensitive design data is of great concern to reactor operators and designers.

The working group also noted that there are potential efficiencies that could result from the IAEA using the reactor operator's equipment for safeguards purposes. This includes the automated fuel loading and unloading equipment to track and monitor the movement of fuel assemblies and the underwater camera that can be used to read the assembly ID number in the core during refueling. While the joint use of equipment would result in improved efficiency and cost reduction for the IAEA, the joint-use of plant equipment by the reactor operator could be hindered by restrictions being placed on the plant operator's use of this equipment by the IAEA. The IAEA must be able to derive independent safeguards conclusions from the use of the safeguards equipment, including joint-use equipment. It is important to recall that the IAEA has been using joint-use equipment with plant operators and State Regulator/SSACs for decades. Active and early discussion between the IAEA, State Regulator/SSAC, and the facility operator typically clarifies whatever restrictions or limitations may result. All parties can then decide whether jointly using equipment is in their mutual interest.

Guidelines versus Prescriptions

SBD should be promoted by way of general guidance that is not overly prescriptive. Guidance that describes the safeguards issues, rather than prescribes how to address them, may be more readily adopted by the facility designers and operators. Dictating specific technology solutions for facility safeguards would be challenging due to the variability in facility designs that prevent "one-size-fits-all" solutions. Instead, guidance could provide descriptions of standards for accuracy, precision, and validation of results. This approach may also help industrial partners to tailor technologies to their facilities so as to reduce the overall impact of safeguards on facility operations.

Safeguards by Design: Voluntary or Mandatory?

SBD is in fact not wholly voluntary in the United States, because the U.S. Nuclear Regulatory Commission (NRC) requires certain domestic nuclear safeguards and security requirements and features. Consequently, all U.S. nuclear power plants have had to be designed or retrofitted to meet domestic (NRC) requirements. Since retrofits are costly, a focus on the potential economic savings achievable through SBD would help promote the concept.

As a process, SBD requires early collaboration between all of the stakeholders - specifically, the IAEA, State Regulator/SSAC, the facility owner/operator, and the designer. The roles and responsibilities of each stakeholder in the process, and the degree of interaction need to be more clearly defined. Based on the successful initial implementation of SBD in countries such as Canada, a tri-lateral mechanism for promoting SBD (i.e., involving the IAEA, State Regulator/SSAC, and facility owner/operator/designer) appears feasible.

The general portion of the IAEA Model Subsidiary Arrangements to the Safeguards Agreement, Code 3.1, requires the State Regulator/SSAC to provide preliminary design information (pertinent to safeguarding the facility) to the IAEA as soon as an official decision is made to construct the facility. Therefore, elements of SBD (e.g., provision of design information to the IAEA early in the process) are already specified and required in accordance with existing international safeguards agreements.

Canada requires the implementation of SBD to some degree since Canadian nuclear regulations require the nuclear facility owner/operator to demonstrate that any new nuclear facility will have strong nuclear safeguards. It is therefore possible that the design of the Dry Storage Containers (DSC) for CANDU reactor spent fuel and the design of the ACR-1000 by AECL will provide a successful demonstration of SBD.

Importance of Containment and Surveillance (C/S)

Japan has the largest number of nuclear facilities under IAEA safeguards of any Member State. Properly designing the nuclear facility from the beginning can reduce the IAEA safeguards inspection effort. Reactors are item facilities where safeguards measures can be simpler than at bulk-handling facilities (e.g., fuel fabrication and reprocessing plants). Since containment and surveillance (C/S) measures are the fundamental safeguards measures used for power reactors, designers need to be aware of the containment and surveillance systems typically used by the IAEA, and account for these in the design of facilities. More advanced safeguards technologies could reduce the need to re-measure and re-verify nuclear material (i.e., fresh, spent, and MOX fuel), which otherwise is a major burden for facility operators. Based on the increased use of IAEA field inspectors to verify the receipt of fresh MOX fuel, because it requires monthly or quarterly verification, there is an apparent need to use more advanced C/S measures for MOX in fresh fuel storage, and for verifying receipts at the reactor. The latter could potentially be done using automated equipment, as is done in the MOX fuel fabrication plants. The combination of using automated MOX fuel receipt verification and more advanced C/S measures for fresh MOX in storage at the reactor could dramatically reduce IAEA field inspections for this purpose, and the resultant burden on the reactor operator.

Business Case for Safeguards by Design

The cost benefits that would arise from implementing SBD – especially in avoiding later costs of retrofitting the facility for nuclear safeguards – should be clarified for the nuclear industry. The successful implementation of SBD will ultimately require a successful business case. Unless the benefits are real and obvious to the commercial nuclear industry, SBD will not be embraced. The working group therefore recommends development of several case studies of safeguards-related retrofits that include an estimate of the costs of implementing safeguards retroactively.

Facility Safeguardability Analysis (FSA)

Working group participants expressed the view that there is a need to formalize the analysis of facility safeguardability and design options, including consideration of trade-offs and evaluation of costs. This issue will be addressed in part by a report being prepared by a U.S. DOE National Laboratory team on the use of Facility Safeguardability Analysis (FSA) to help facility designers meet IAEA safeguards requirements. FSA incorporates information on nuclear material diversion paths, design trade-offs, and cost/benefit analyses. In essence, FSA formalizes safeguards analysis during the design stage and is intended to help build the business case for promoting SBD.

CONCLUSIONS AND RECOMMENDATIONS

General SBD Recommendations

1. Nuclear facility designers should be provided information that clearly explains the requirements for domestic safeguards, international safeguards, security, and physical protection early in the design stage. It is ineffective for the designer to address these issues as separate design requirements involving separate stakeholders. (The IAEA is currently updating the Nuclear Safety and Security Series of documents, which provides guidance to industry in these areas. The IAEA should consider folding the safeguards requirements into this guidance document, or issuing a comparable document to present safeguards requirements to the nuclear industry in the same manner.)

2. Nuclear facility designers should provide for the space, utility access, and other infrastructure requirements for IAEA seals, surveillance systems, fuel flow monitors, and the possible remote transmission of safeguards data.

3. The IAEA should update safeguards requirements and make them available to the broader international safeguards community and nuclear industry, through the State Regulator/SSAC.

4. The IAEA, Member State governments, national laboratories, State regulator/SSACs, and commercial equipment suppliers should establish an annual joint forum to share the latest developments in safeguards technology and equipment with nuclear facility operators and facility designers. This would enable nuclear facility operators and designers to become aware of promising technology and equipment that could address challenging safeguards issues more efficiently.

5. International safeguards stakeholders should support the IAEA by preparing a business case that shows the clear advantages to the commercial nuclear industry of implementing SBD – i.e., that the cost of incorporating safeguards measures in the design stage is cheaper and less disruptive than implementing safeguards measures and features after the plant begins operation.

SBD Recommendations for Nuclear Reactors

1. The IAEA should make greater use of the nuclear power plant operator's instruments for the purpose of nuclear safeguards, particularly for monitoring reactor power output and verifying the identification of fuel assemblies. The plant operator's refueling machines should automatically track assemblies as they are moved from fresh fuel storage to the core and from the core to the spent fuel storage pool. This information would enhance the continuity of knowledge of the fresh fuel, core fuel, and spent fuel. Similarly, plant instruments used to monitor the combined power production and output of the reactor could be used to verify the reactor period of use and output, as declared by the plant operator. In such cases, the IAEA would need a means to independently verify the data from the plant instruments in question.

2. The IAEA and the nuclear industry should improve the identification and tracking of nuclear fuel assemblies from cradle to grave. The IAEA currently identifies fuel assemblies at LWRs by visually

verifying the engraved serial number, which is often incomplete. Verification of the assembly number becomes difficult when the assembly is highly irradiated and heavily oxidized.

3. Designers of nuclear power plants should design the spent fuel storage pools, transfer canals, and spent fuel transfer systems so that spent fuel transfers can be easily monitored by the IAEA. Design suggestions include providing a clear line-of-sight for IAEA surveillance cameras to cover the pool and transfer canal, minimizing the number of baskets, containers, or casks for transferring spent fuel, and designing the spent fuel transfer process to be more easily monitored by the IAEA's surveillance systems.

4. The verification of spent fuel transfers from the spent fuel pool to interim spent fuel storage facilities should be made more efficient. This guidance will become more important as more spent nuclear fuel is transferred to interim storage as opposed to long-term storage in geologic repositories. Issues to be addressed include verifying spent fuel transfers, maintaining the continuity of knowledge on the spent fuel in interim storage, and re-verifying the spent fuel if the continuity of knowledge is lost. So-called "smart" spent fuel storage containers could maintain the continuity of knowledge of stored spent fuel more effectively.[5] This is analogous to "smart containers" that have been proposed or developed for other storage applications, such as for storing PuO_2/MOX, UF_6, etc.

5. Nuclear power plant designers should incorporate a dedicated area in the spent fuel pool, apart from the main spent fuel storage racks, to permit verification and/or re-verification of spent fuel. The IAEA has difficulty verifying long-cooled or low-burnup fuel by Cerenkov glow when the fuel is among brighter spent fuel assemblies. In addition, more precise non-destructive assay (NDA) methods for detecting the removal of spent fuel pins require the availability of a location away from the main body of stored spent fuel. Lastly, the plant operator's proposed spent fuel re-racking procedure needs to be discussed in advance with the IAEA to determine if the continuity of knowledge of the spent fuel can be maintained.

6. The IAEA should communicate its safeguards requirements for Interim Spent Fuel Storage Installations (ISFSIs) to the nuclear industry through the State Regulator/SSAC.

7. The introduction of MOX fuel for light water reactors has resulted in a greater inspection effort by the IAEA due to the more stringent IAEA verification requirements for Pu-based fuel. An unattended system to verify the receipt and unloading of fresh MOX fuel into fresh fuel storage, which would reduce IAEA on-site verification effort, should be developed.

8. The IAEA should use advanced C/S measures to maintain the continuity of knowledge of fresh MOX fuel in storage at the reactor, which would reduce IAEA field inspection effort for the verification of MOX fuel at LWRs.

9. The IAEA should reconsider the definition of an "item" in special cases involving verified spent nuclear fuel. A verified basket of spent CANDU fuel could be considered an item, as opposed to the individual spent CANDU fuel bundle. Similarly, a container of spent fuel in an interim spent fuel storage facility, which has been verified and monitored by the IAEA prior to welding and

encapsulation, could be viewed as an item. Reconsideration of these points would permit more efficient use of IAEA resources, especially in the case of re-verification.

10. The IAEA and State regulator/SSAC should evaluate and consider promoting the use of the most current burnup codes for calculating and declaring the nuclear material and fissile content of spent nuclear fuel, and should inform plant owners and operators which codes are recommended. The use of obsolete and improvised spent-fuel burnup codes could result in a shipper/receiver difference (SRD) when the spent fuel is sent from the reactor to a reprocessing plant.

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NOTES

[1] International Atomic Energy Agency: IAEA Nuclear Reactor Database, Vienna, Austria, January, 2011; from: http://www.iaea.org.

[2] Pan, P., Boyer, B., Scherer. C. (LANL): *DOE/NNSA Perspective; SBD: Gen-III/III+ Light Water Reactors and Beyond*, Presentation at the Third International Meeting on Next Generation Safeguards, LA-UR-10-08220, Washington D. C., December 14 - 15, 2011.

[3] Okko, O., Honkamaa, T., Kuusi, A., and Rautjarvi, J. (Finland STUK): *Safeguards-by-Design Experiences from New Nuclear Installations*, presentation at the International Nuclear Safeguards Symposium, Vienna, Austria, November, 2010.

[4] The five Nuclear Weapons States (China, France, Russia, the United Kingdom and the United States) as defined by the NPT, all have discrete bilateral Voluntary Offer Safeguards Agreements (VOA) with the IAEA. The stated purpose of the U.S. VOA is to encourage the widespread adherence to the NPT by demonstrating to NNWS that they would "not be placed at a commercial disadvantage by reason of the application of safeguards pursuant to the Treaty." The VOA obligates the United States to provide the Agency with a list of facilities within the United States not associated with activities of direct national security significance to the United States. The IAEA may "from time to time, identify to the United States, those facilities selected from the then current list provided by the United States…in which the Agency wishes to apply safeguards…" The safeguards to be implemented by the Agency under the VOA "shall be implemented by the same procedures followed by the Agency in applying its safeguards on similar facilities in Non-Nuclear Weapon States…" Currently, there are approximately 300 nuclear facilities on the U.S. eligible facilities list.

[5] The term "smart spent storage containers," as used here, means that containment features are directly integrated into the Dry Spent Fuel Transport/Storage Container to provide for continuous Continuity-of-Knowledge of the spent fuel stored within, or enhanced tracking, or both. Such features could take the form of integrated electronic seals, movement sensors integrated into the container lid, container tracking with automatic and continuous data up-link, etc. These features would provide enhanced and built-in tamper indication or continuous and real-time knowledge regarding the location and disposition of the container, or both.

APPENDIX 6: MEETING AGENDA

Meeting Objective: *To draw together international stakeholders to promote a common understanding of Safeguards by Design principles and goals and to develop guidance for practical application of the concept in four types of new civil nuclear facilities.*

Tuesday, December 14

Time	**Session**	**Location**
9:00	**Arrival and Registration**	Crystal Corridor
9:30	**Opening Remarks**	Jefferson Room

Thomas P. D'Agostino, U.S. Under Secretary for Nuclear Security and NNSA Administrator

9:45	**Keynote Address**	Jefferson Room

Daniel B. Poneman, U.S. Deputy Secretary of Energy

10:15	**Break**	Crystal Corridor
10:45	**Safeguards by Design Program Strategies**	Jefferson Room

Session Chair: Kasia Mendelsohn, NNSA

Presentations:
International Atomic Energy Agency (IAEA) Safeguards by Design Program
Bruce Moran, IAEA

U.S. Next Generation Safeguards Initiative (NGSI) Safeguards by Design Program
Dunbar Lockwood, NNSA

12:00	**Working Lunch**	Lincoln Room West
13:30	**Safeguards by Design Lessons Learned: Enrichment & Reactors**	Jefferson Room

Session Chair: John Carlson, Consultant

Presentations:
Safeguards Lessons Learned from URENCO Enrichment Plants
Peter Friend, URENCO Limited

Safeguards Lessons Learned From CANDU Reactors
Jeremy Whitlock, Atomic Energy of Canada Limited

15:00	**Break**	Crystal Corridor

15:30	**Safeguards by Design Lessons Learned: Fuel Fabrication & Reprocessing**	Jefferson Room

Session Chair: Dr. Yusuke Kuno, Japan Atomic Energy Agency

Presentations:
Safeguards Lessons Learned from MELOX Fuel Fabrication Plant
Michael McMahon, AREVA- U.S.

Safeguards Lessons Learned from Rokkashomura Reprocessing Plant
Tomonori Iwamoto, Japan Nuclear Fuel Limited

17:00	**Day 1 Wrap-Up and Preview of Day Two**	Jefferson Room

Host Remarks*:* Kasia Mendelsohn, NNSA

18:00-20:00	**Reception**	Cabinet Room

Wednesday, December 15

9:00	**Working Group Sessions**

Topic	Moderator	Location
Nuclear Reactors	Brian Boyer, Los Alamos National Laboratory	Georgetown West
Enrichment Facilities	Michael Whitaker, Oak Ridge National Laboratory	Georgetown East
Reprocessing Facilities	Mark Schanfein, Idaho National Laboratory	Lincoln West
Fuel Fabrication Facilities	Trond Bjornard, Idaho National Laboratory	Lincoln East

10:30	**Break**
11:00	**Working Group Sessions (continued)**
12:30	**Working Lunch**
13:30	**Working Group Sessions (continued)**
15:00	**Break**
15:30	**Working Group Sessions (continued)**
17:00	**Review Key Points and Draft Working Group Summary**
17:30	**Closing Plenary**

Working Group Reports: Moderators
Meeting Chair Closing Remarks: Kasia Mendelsohn, NNSA

18:00	**Adjourn**

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APPENDIX 8: GLOSSARY OF ACRONYMS

ABACC	Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
AECL	Atomic Energy of Canada Limited
BWR	Boiling Water Reactor
C/S	Containment and Surveillance
CANDU	Canada Deuterium Uranium Reactor
CEA	French Alternative Energies and Atomic Energy Commission
CoK	Continuity of Knowledge
DA	Destructive Assay
DC&E	Data Collection and Evaluation
DIE	Design Information Examination
DIQ	Design Information Questionnaire
DIV	Design Information Verification
DOE	U.S. Department of Energy
DOS	U.S. Department of State
DSC	Dry Storage Containers
EFL	Eligible Facility List
F/W	Feed and Withdrawal
FKMP	Flow Key Measurement Point
FMCT	Fissile Material Cutoff Treaty
FSA	Facility Safeguardability Analysis
FSV	Flow Sheet Verification
GCEP	Gas Centrifuge Enrichment Plant
HEU	Highly Enriched Uranium
HTGR	High Temperature Gas Reactor
IAEA	International Atomic Energy Agency
IAT	Input Accountability Tank
ID	Identification
IIV	Interim Inventory Verification
IKMP	Inventory Key Measurement Points
INB	Indústrias Nucleares do Brasil
INFCIRC	IAEA Information Circular
INL	Idaho National Laboratory
INMM	Institute of Nuclear Materials Management
ISFSI	Interim Spent Fuel Storage Installation
ITV	International Target Values
JAEA	Japan Atomic Energy Agency
JMOX	Japanese MOX Fuel Fabrication Plant
JNFL	Japan Nuclear Fuel Limited
KMP	Key Measurement Point
LANL	Los Alamos National Laboratory
LEU	Low Enriched Uranium

LFUA	Limited Frequency Unannounced Access
LLNL	Lawrence Livermore National Laboratory
LWR	Light Water Reactor
MBA	Material Balance Area
MFFF	MOX Fuel Fabrication Facility
MOX	Mixed Oxide Fuel
MPC&A	Material Protection, Control, and Accounting
MTHM	Metric Ton of Heavy Metal
MUF	Material Unaccounted for
NDA	Nondestructive Assay
NFCIS	Nuclear Fuel Cycle Information System
NGS3	The Third Meeting on Next Generation Safeguards
NGSI	The Next Generation Safeguards Initiative
NIS	The Office of Nonproliferation and International Security
NM	Nuclear Material
NMA	Nuclear Materials Accountancy
NMP	Nuclear Management Partners
NNSA	National Nuclear Security Administration
NNWS	Non-Nuclear Weapon State
NPT	The Nuclear Non-Proliferation Treaty
NRC	U.S. Nuclear Regulatory Commission
NRTA	Near-Real-Time Accountancy
NWS	Nuclear Weapon State
OAT	Output Accountability Tanks
ORNL	Oak Ridge National Laboratory
OTDR	Optical Time Domain Reflectometers
PBMR	Pebble Bed Modular Reactor
PFFF	Plutonium Fuel Fabrication Facility
PIV	Physical Inventory Verification
PM	Process Monitoring
PMDA	Plutonium Management and Disposition Agreement
PNNL	Pacific Northwest National Laboratory
PWR	Pressurized Water Reactor
QA/QC	Quality Assurance/ Quality Control
R&D	Research and Development
RII	Random Interim Inspections
RRP	Rokkasho Reprocessing Plant
RSAC	Regional System for Accountancy and Control
SAL	Safeguards Analytical Laboratory
SBD	Safeguards by Design
SGCP	IAEA Division of Safeguards Concepts and Planning
SMMS	Solution Measurement Monitoring System
SMP	Sellafield MOX Plant

SMR	Small Modular Reactor
SnF	Sign and Forward
SNL	Sandia National Laboratory
SNRI	Short Notice Random Inspection
SOH	State of Health
SQ	Significant Quantity
SRD	Shipper/Receiver Difference
SRNL	Savannah River National Laboratory
SSAC	State System for Accounting and Control of Nuclear Material
STIE	Sealed Tamper-Indicating Enclosure
SWU	Separative Work Unit
TIE	Tamper-Indicating Enclosure
TRP	Tokai Reprocessing Plant
UK-NNL	United Kingdom National Nuclear Laboratory
UMI	Unmeasurable Inventory
UPS	Uninterruptible Power Supply
URS	United Research Services
VOA	Voluntary Offer Agreement