LA-UR- 11-05726

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Intended for: Publication for Global 2011
December 12-15, 2011
Chiba, Japan

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Safeguards and Security by Design (SSBD) for the Domestic Threat – Theft and Sabotage

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Abstract

Safeguards by Design (SBD) is receiving significant interest with respect to international safeguards objectives. However, less attention has been focused on the equally important topic of domestic Safeguards and Security by Design (SSBD), which addresses requirements such as those of the Nuclear Regulatory Commission (NRC) in the United States. While international safeguards are concerned with detecting State diversion of nuclear material from peaceful to nuclear explosives purposes, domestic Material Protection, Control and Accounting measures (MPC&A) are focused on non-State theft and sabotage. The International Atomic Energy Agency (IAEA) has described the Safeguards by Design (SBD) concept as an approach in which "international safeguards are fully integrated into the design process of a new nuclear facility from the initial planning through design, construction, operation, and decommissioning." This same concept is equally applicable to SSBD for domestic requirements. The United States Department of Energy (DOE) has initiated a project through its Office of Nuclear Energy (NE) and more specifically its Fuel Cycle Research and Development (FCRD) program, to develop a domestic SSBD discipline and methodology in parallel with similar efforts sponsored by the DOE Next Generation Safeguards Initiative (NGSI) and the IAEA for international safeguards. This activity includes the participation of industry (through DOE-sponsored contracts) and DOE National Laboratories. This paper will identify the key domestic safeguards and security requirements (i.e. MC&A and physical protection) and explain how and why Safeguards and Security by Design (SSBD) is important and beneficial for the design of future US nuclear energy systems.

1.0 Introduction

The United States Department of Energy (DOE) has initiated a project through its Office of Nuclear Energy (NE) and more specifically its Fuel Cycle Research and Development (FCRD) program, to develop a domestic SSBD discipline and methodology in parallel with similar efforts sponsored by the DOE Next Generation Safeguards Initiative (NGSI) and the IAEA for international safeguards. The development of a Safeguards and Security by Design methodology for the domestic threat must start with a clear understanding of the applicable safeguards and security requirements. While requirements (and/or objectives) for international safeguards have been developed by the International Atomic Energy Agency (IAEA) in support of the nuclear Nonproliferation Treaty (NPT) (INFCIRC/153/corrected) and its predecessors (e.g. INFCIRC/ 66/Rev 2,) to prevent State diversion of nuclear material for weapons production, requirements for domestic safeguards and security originate through state legislation to prevent sub-national (including the insider) theft of nuclear material and sabotage. Often domestic safeguards and security are referred to as material control and accounting (MC&A) and physical protection.

For nuclear weapons states (NWSs) acquisition of technology for the production of nuclear energy has generally been developed within the state in parallel with their weapons programs. Because domestic programs for safeguards and security have been necessary for their weapons programs, the U.S. and European NWSs have possessed the knowledge within the state to develop domestic safeguards and security requirements for the commercial production of nuclear power (i.e. U.S. Nuclear Regulatory Commission and EURATOM). For non-nuclear weapons States (NNWSs) acquisition of technology for the production of nuclear energy has generally come from outside of the state rather than within through import from NWSs. Without the experience of weapons programs, NNWs usually lack the knowledge to develop safeguards and security requirements for the commercial production of nuclear power. As such, NWSs have often relied on IAEA guidance for developing their domestic State Regulatory Authorities (SRAs) and related domestic safeguards and security requirements. This IAEA guidance includes Guidelines for States' Systems of Accounting (SSAC) for and Control of Nuclear Materials (IAEA/SG/INF/2), and the IAEA Nuclear Security Series No. 13: IAEA Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev 5).

The DOE NE's Fuel Cycle R&D Program is concerned with development of the U.S. domestic fuel cycle, and as such domestic regulatory requirements are of primary interest. However, development of an effective SSBD methodology for the U.S. nuclear fuel cycle must also consider that the same technology may be exported to other countries with their own State Regulatory Authorities (SRAs). Therefore, a sound domestic Safeguards and Security by Design (SSBD) discipline must begin with knowledge of IAEA guidance for domestic safeguards and security, as well as requirements of individual SRAs.

While this paper is focused on domestic safeguards and security, it is important to note the connection between domestic and international (e.g. IAEA) safeguards. As stated in paragraph 7 of INFCIRC/153 (Corrected), "…the State shall establish and maintain a system of accounting for and control of all nuclear material subject to safeguards under the Agreement, and that such safeguards shall be applied in such a manner as to enable the Agency to verify, in ascertaining there has been no diversion of nuclear material…" Paragraph 7 can be restated as, domestic MC&A used to reduce the risk of sub-national nuclear material theft, should also enable international safeguards that are used to reduce the risk of State diversion of nuclear material.

The basis for SSBD is summarized by Figure 1. As a design matures the cost for design changes increases, and the ability to influence the design in an efficient fashion decreases. As these effects are relatively obvious, this behavior does not need a great deal of discussion. Suffice it to say, with the complexity of modern nuclear facilities, one small design change can ripple through an integrated design. This has a tendency to limit the degree of design changes (e.g. opportunity of influence) and create a far-reaching impact on the integrated design (e.g. cost of changes).

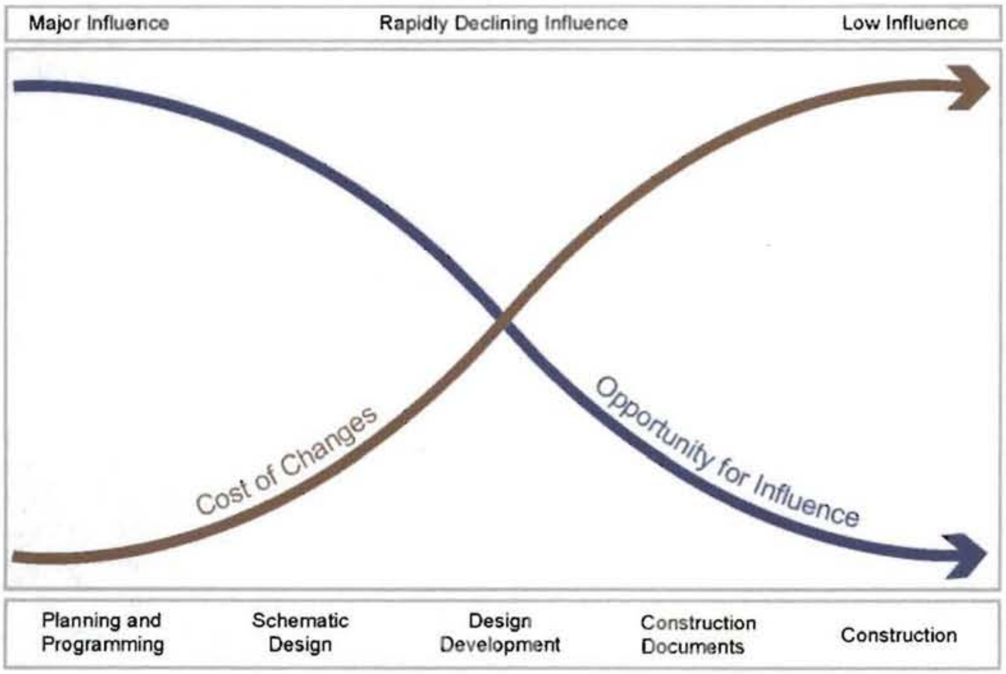

Figure 1. Cost of changes and opportunity for influence as design mature [1]

2.0 Discussion

While the domestic and international threats may differ, the objectives and/or requirements for both, for safeguarding of nuclear material are concerned with the detecting the loss of a significant quantity of material within a limited period of time at high confidence. For both domestic and international safeguards, the primary means for satisfying these objectives and requirements is nuclear material accountancy (NMA). However, as with any reliable defense, detection is based on defense-in-depth thereby requiring additional measures to NMA. As an example, these additional measures include containment and surveillance (C/S), which can include equipment such as seals and cameras respectively. Where objectives and/or requirements differ for the domestic and international threats is verification of the reporting. For domestic safeguards the reporting is verified by the State through its SRA through on-site inspections and/or auditing of the operator's data. For international safeguards the reporting is verified by the IAEA through on-site inspections, independent measurements, and/or authentication of operator's data. Consequently, the design of an international safeguards system usually requires an additional later of independent instrumentation and equipment superimposed on the domestic safeguards system. However, the domestic safeguards system forms the basis of the measurements used by the State to demonstrate that its Declaration to the IAEA is being honored.

For NMA, detecting the loss of a significant quantity of material within a limited period of time at high confidence can be defined differently by the State SRA and IAEA in accordance with their threats. One can loosely define he IAEA's definition of a significant quantity as that required for a weapon and the time period as less than that required for a State to fabricate a weapon. For domestic safeguards the State may be interested in a quantity of material less than that required for a weapon but enough to permit a subversive act. Also, given the nature of a subversive act, the detection time for domestic safeguards may be less than international. If the State knows that international safeguards will be imposed upon its facility (i.e NWS), the domestic safeguards system must not preclude and would preferably enable, measurements for the State Declaration to the IAEA. Therefore, the designer of domestic safeguards must be cognizant of the international safeguards objectives.

Security does not have domestic and international analogs as does safeguards, but rather security is primarily a domestic responsibility of the State. However, due to the legitimate export of nuclear technology and materials, bilateral security agreements have been formed to assure that the recipient is properly protecting the exported technology and materials. As these bilateral agreements became more common, standardization of security requirements was achieved through IAEA guidance. Therefore, as in the case of safeguards, both State regulations and IAEA guidance exist for security, for which regulation is ultimately the responsibility of the SRA.

2.1 Safeguards Guidance and Requirements

2.1.1 International Guidelines for Domestic Regulation of Safeguards

In accordance with IAEA INFCIRC/153, The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Nonproliferation of Nuclear Weapons, said States shall establish and maintain a system of accounting and control of all nuclear material subject to safeguards under the Agreement. The basic elements of the safeguards are set forth in paragraph 32 of INFCIRC/153 (Corrected). These basic elements could be considered the most universal set of domestic safeguards requirements world-wide.

In accordance with IAEA/SG/INF/2, Guidelines for States' Systems of Accounting for and Control of Nuclear Materials, a system of accounting for and control of nuclear material may have, among other things, the following objectives:

- A national/domestic objective to account for and control nuclear material in the State and to contribute to the detection of possible losses by theft, or unauthorized use of nuclear material,
- An international objective to provide the essential basis for the application of IAEA safeguards.

It is for each State to decide whether or not it wishes to establish one combined system or independent systems to pursue these different objectives. As stated in paragraph 32 of INFCIRC/153, a States' System of Accounting for and Control of Nuclear Material shall be based on a structure of material balance areas (MBAs), and shall make provision as appropriate for the establishment of such measures as:

- A measurement system for the determination of the quantities of nuclear material received, produced, shipped, lost or otherwise removed from inventory, and the quantities of the inventory;
- The evaluation of precision and accuracy of measurements and the estimation of measurement uncertainty;
- Procedures for identifying, reviewing and evaluating differences in shipper/receiver measurements;
- Procedures for a taking a physical inventory;
- Procedures for the evaluation of accumulations of unmeasured inventory and unmeasured losses;
- Systems of records and reports showing, for each MBA, the inventory of nuclear material and the changes in that inventory including receipts into and transfers out of the MBA;
- Provisions to ensure that the accounting procedures and arrangements are being operated correctly; and
- Procedures for the provisions of reports to the Agency.

2.1.2 Domestic Requirements for Safeguards in the United States

In the U.S., the Nuclear Regulatory Commission (NRC) serves as the SSAC and is responsible for domestic regulation of nuclear facilities. However, to say the NRC exists only to fulfill U.S. obligations to the NPT and its Safeguards Agreement with the IAEA, would be incorrect. Before the NRC was created, nuclear regulation in the U.S. was the responsibility of the Atomic Energy Commission (AEC), which Congress first established in the Atomic Energy Act of 1946, well before the NPT or its predecessors. Eight years later, Congress replaced that law with the Atomic Energy Act of 1954, which for the first time made the development of commercial nuclear power possible. This act assigned the AEC the functions of both encouraging the use of nuclear power and regulating its safety. As time progressed, supporters and critics of nuclear power agreed that the promotional and regulatory duties of the AEC should be assigned to different agencies. The Energy Reorganization Act of 1974 created the Nuclear Regulatory Commission; it began operations on January 19, 1975. The NRC focuses its attention on issues that are essential to protecting public health and safety.

NRC MC&A regulations are defined in 10 CFR 74, Material Control and Accounting of Special Nuclear Material. The MC&A requirements of 10 CFR 74 differ to a large degree for material of Low Strategic Significance, material of Moderate Strategic Significance, and Strategic Special Nuclear Material.

This part has been established to contain the requirements for the control and accounting of special nuclear material at fixed sites and for documenting the transfer of special nuclear material. General reporting requirements as well as specific requirements for certain licensees possessing special nuclear material of low strategic significance, special nuclear material of moderate strategic significance, and formula quantities of strategic special nuclear material are included. Requirements for the control and accounting of source material at enrichment facilities are also included.

The NRC provides separate MC&A requirements for nuclear material of low strategic significance, moderate strategic significance, and strategic special nuclear material. Example requirements follow that are found in 10 CFR 74.51, Subpart E--Formula Quantities of Strategic Special Nuclear Material

- Each licensee who is authorized to possess five or more formula kilograms of strategic special nuclear material (SSNM) and to use such material at any site, other than a nuclear reactor licensed pursuant to part 50 of this chapter, an irradiated fuel reprocessing plant, an operation involved with waste disposal, or an independent spent fuel storage facility licensed pursuant to part 72 of this chapter shall establish, implement, and maintain a Commission-approved material control and accounting (MC&A) system that will achieve the following objectives:
- To achieve the general performance objectives specified in § 74.51(a), the MC&A system must provide the capabilities described in §§ 74.53, 74.55, 74.57 and

74.59 and must incorporate checks and balances that are sufficient to detect falsification of data and reports that could conceal diversion by:

- Each applicant for a license, and each licensee that, upon application for modification of a license, would become newly subject to paragraph (a) of this section, shall submit a fundamental nuclear material control (FNMC) plan describing how the MC&A system shall satisfy the requirement of paragraph (b) of this section. The FNMC plan shall be implemented when a license is issued or modified to authorize the activities being addressed in paragraph (a) of this section, or by the date specified in a license condition.
- Notwithstanding § 74.59(f)(1), licensees shall perform at least three bimonthly physical inventories after implementation of the NRC approved FNMC Plan and shall continue to perform bimonthly inventories until performance acceptable to the NRC has been demonstrated and the Commission has issued formal approval to perform semiannual inventories. Licensees who have prior experience with process monitoring and/or can demonstrate acceptable performance against all Plan commitments may request authorization to perform semiannual inventories at an earlier date.

2.2 Security Guidance and Requirements

2.2.1 International Guidelines for Domestic Regulation of Security

The IAEA Nuclear Security Series No. 13: IAEA Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev 5) recommends physical protection requirements that should be implemented by States for the application of IAEA nuclear security fundamental principles. The INFCIRC/225/Rev 5 applies to physical protection of unauthorized removal of nuclear material, including its transport, and of nuclear facilities against sabotage on site. This publication is complementary to and consistent with other IAEA Nuclear Security Recommendations on:

- Radioactive Material and Associated Facilities (IAEA Nuclear Security Series No. 14) – protection requirements against unauthorized removal of nuclear material for potential subsequent off-site dispersal.
- Nuclear and Other Radioactive Material out of Regulatory Control (IAEA Nuclear Security Series No. 15) – requirements undertaken to locate and recover material after the reporting of lost, missing or stolen nuclear material to a competent authority according to national regulations.

The INFCIRC/225/Rev 5 defines the objectives of the State's nuclear security regime as

- To protect against unauthorized removal.
- To locate and recover missing nuclear material.

- To protect against sabotage.
- To mitigate or minimize effects of sabotage.

The State's physical protection regime should seek to achieve these objectives through

- Prevention of a malicious act by means of deterrence and by protection of sensitive information.
- Management of an attempted malicious act or a malicious act by an integrated system of detection, delay, and response.
- Mitigation of the consequences of a malicious act.

The following subsections attempt to provide a concise set of physical protection requirements screened from the INFCIRC/225/Rev 5 for unauthorized removal of nuclear material and nuclear facilities against sabotage on site. Physical protection requirements from IAEA Nuclear Series No. 14 and 15 have also been included in the selection process. Those selected represent the authors' best interpretation of these three key IAEA requirement documents, as grouped into two categories in physical protection:

- Group A: Specific requirements for designers,
- Group B: Requirements for operators, licensees, regulators; should be considered for designers.

Only Group A requirements are presented in the text. All Group B requirements are included in Appendix A. ***Best SSBD practices recommended by the authors' to meet requirements are presented in the text in the italic form.***

Designers should

- Take physical protection into account as early as possible in site selection and design.
- Address proper interface for physical protection, safety, and nuclear material accountancy and control.
- Work with the State to define design basis threat and unacceptable radiological consequences.
- Work with the State to define the threat and associated capabilities in the form of a threat assessment. Threats from insider and external adversaries should both be included in the design basis threat.
- Use a graded approach, that is, the level of physical protection should depend on the categories of the material attractiveness, or levels of unacceptable radiological consequences.
- Work with the State to ensure that the State's protection regime is capable of establishing and maintaining the risk of unauthorized removal and sabotage at acceptable levels through risk management.
- Establish risk tables as soon as the design basis threat is developed. Risk should be managed by
    - Reducing the potential consequence of malicious acts.

    - Improving the effectiveness of physical protection system (both likelihood and consequence).
- Identify pathways for prevention of incidents and mitigation of consequence and integrate prevention and mitigation strategies into design.
- Use the more stringent requirements for physical protection based on either those against unauthorized removal or those against sabotage.

2.2.2 Domestic Requirements for Security in the United States

In the U.S., the Nuclear Regulatory Commission (NRC) is responsible for domestic regulation of nuclear facilities. NRC requirements for physical security are defined in 10 CFR 73, Physical Protection of Plants and Materials.

This part prescribes requirements for the establishment and maintenance of a physical protection system which will have capabilities for the protection of special nuclear material at fixed sites and in transit and of plants in which special nuclear material is used. The following design basis threats, where referenced in ensuing sections of this part, shall be used to design safeguards systems to protect against acts of radiological sabotage and to prevent the theft or diversion of special nuclear material.

Example requirements follow that are found in 10 CFR 73.50, Requirements for Physical Protection of Licensed Activities.

- The licensee shall establish a security organization, including guards, to protect his facility against radiological sabotage and the special nuclear material in his possession against theft.

- The licensee shall locate vital equipment only within a vital area, which, in turn, shall be located within a protected area such that access to vital equipment requires passage through at least two physical barriers. More than one vital area may be within a single protected area.

- The licensee shall control all points of personnel and vehicle access into a protected area, including shipping or receiving areas, and into each vital area. Identification of personnel and vehicles shall be made and authorization shall be checked at all points.

- All alarms required pursuant to this part shall annunciate in a continuously manned central alarm station located within the protected area and in at least one other continuously manned station, not necessarily within the protected area, such that a single act cannot remove the capability for calling for assistance or otherwise responding to an alarm. All alarms shall be self-checking and tamper indicating. The annunciation of an alarm at the onsite central station shall indicate the type of alarm (e.g., intrusion alarm, emergency exit alarm, etc.) and location.

2.3 How and why Safeguards and Security by Design (SSBD) is important and beneficial for the design of future US nuclear energy systems.

As briefly discussed in the Introduction section of this paper, as a design matures the cost for design changes increases, and the ability to influence the design in an efficient fashion decreases. Encouraging SSBD as an industry norm should enable the most effective safeguards and security design for the least cost. Since safeguards and security are paramount to the successful promotion and implementation of advanced nuclear energy systems, a robust R&D program for the development of a SSBD methodology acceptable to both the regulators and industry is important and beneficial for the design of future U.S. nuclear energy systems.

3.0 Conclusions

The development of a Safeguards and Security by Design methodology for the domestic threat must start with a clear understanding of the applicable safeguards and requirements. This study has identified these requirements as the responsibility of SRAs such as EURATOM and the U.S. NRC. For states with SRAs not as well developed as EURATOM and the NRC, guidelines for domestic MC&A and physical security requirements can be found in IAEA guidance including Guidelines for States' Systems of Accounting (SSAC) for and Control of Nuclear Materials (IAEA/SG/INF/2), and the IAEA Nuclear Security Series No. 13: IAEA Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev 5). Therefore, a sound domestic Safeguards and Security by Design (SSBD) discipline must begin with knowledge of IAEA guidance for domestic safeguards and security, as well as requirements of individual SRAs.

4.0 References

(1) The National Institute of Building Science, 29 September 2011, www.wbdg.org/design/dd_archprogramming.php