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Development of IAEA High Level Guidelines for Designers and Operators - Safeguards-By-Design

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Abstract. At the end of 2008, the IAEA launched a new task on "Guidance for Designers and Operators and Measures to facilitate the implementation of Safeguards at Future Nuclear Cycle Facilities", contributed by EURATOM and other MS Support Programmes, whose goal is to formulate "safeguards by design", or SBD, Guidelines to designers and operators.

SBD is a process that facilitates the implementation of international safeguards by taking into account requirements and guidelines very early in the design phase. To this scope, the legal framework and the interaction among the stake-holders need to be improved.

The overall process can thus be made more effective and efficient without costly back-fitting and iterations.

In this context, at the end of 2008, the IAEA launched a new task on "Guidance for Designers and Operators and Measures to facilitate the implementation of Safeguards at Future Nuclear Cycle Facilities", with contributions by EURATOM and other Member State Support Programmes (MSSP).

A first set of high level guidelines of the IAEA Safeguards by Design series was drafted by EURATOM experts, and will be the basis for further improvements.

This paper will develop on the contents of the document, as well as on methodological developments.

Facility specific guidelines will have to be prepared to serve as reference for the design of new evolutionary and innovative facilities. All this will be achieved within useful deadlines with the contributions of other support programmes.

1. Introduction

Safeguarding the nuclear fuel cycle is a corner stone of proliferation resistance. Design choices are the result of an optimal compromise among economic, operational, safety and security factors, which should also take into account the requirements for application of safeguards at an early stage.
However, international safeguards are often introduced too late into a consolidated facility design, resulting in costly redesign and project delays. Instead, by taking into account design features that facilitate the implementation of international safeguards very early in the design phase, a concept known as "safeguards by design" (SBD), the overall process could be made more effective and efficient with benefits to all the involved stake-holders.
To achieve this, the IAEA is in the process of developing SBD as an approach whereby safeguards are fully integrated into the design process of a nuclear facility, from the initial planning through design, construction, operation, and decommissioning.
With this aim, on October 28-31, 2008 the IAEA convened the "Facility Design and Plant Operation Features that Facilitate the Implementation of IAEA Safeguards" workshop, with participants from Member States, the European Commission, nuclear industry, and the IAEA, whose results are reported in [1]. Based on its conclusions, the IAEA started to review the overall framework and timeline of interaction among the various stake-holders, including the update of the existing safeguards documentation, and to develop a series of new SBD guidelines, which should be concluded in 2011 covering all facility types, i.e. enrichment, fuel fabrication, reactors, reprocessing plants and final repositories. This will be particularly important for developmental facilities relying on equipment and design still in the R&D phase.
The EURATOM Support Programme undertook the task of drafting the first high level guidance document of the SBD Series, which is the object of this paper.

2. Brief recall of IAEA Safeguards approaches

IAEA's safeguards system for verification of declarations is implemented by:

- Design information verification (DIV);
- Nuclear material accountancy and control (NMAC), verified by inspections
- Containment and Surveillance (C/S) measures to monitor access or movements of the nuclear material

It is necessary that the nuclear safeguards inspectors have a clear idea of the final boundary of the nuclear Material Balance Areas at the start of the design so that they can plan their strategy for locating or installing safeguards instrumentation. This is also an important fact in the identification of the key measurement points for safeguarding the nuclear material within the facility. Knowing the normal operational route of nuclear material through the plant the inspector must then examine the other possible diversion or non standard operational routes and decide on the credibility of such routes for clandestine removal of nuclear material. Having identified the possible diversion routes, the IAEA must work with the designers and operators to eliminate or minimize the risk associated with the pathways.

2.1 Design information

Much of the information required by the IAEA to plan the safeguards approach is provided by the operators/designers through the SSAC with the design information questionnaire (DIQ) after the comprehensive safeguards agreement (CSA) between the State and the IAEA has been concluded or when a new facility is planned.
The DIQ is followed by the design information verification (DIV), performed during a visit and not to be confused with the inspections for verification of materials.
Design information is an important activity that should commence as soon as possible in the design and construction cycle. It is a must that the inspectors gain access as soon as practicable in the design and construction phase. Checks on the progress and the construction early on in the project will allow the inspectors to have access to all areas including those that will be closed off or be inaccessible at a later stage of the construction. Visiting the plant during the early and later stages of construction will enable modifications or adjustments to be made without severely impacting eventual facility operations. Detailed reports of these inspections must ensure that the identified safeguards important locations and access route openings are accurately recorded and reported. As the facility moves into

the commissioning phase confirmation of the correctness of the measures proposed, designed, and implemented can be confirmed.

2.2 Nuclear material accountancy and control

The purpose of the nuclear material accountancy and control (NMAC) system is to establish the quantities and locations of the nuclear material present in a nuclear facility and the changes that take place in these quantities and locations. The essential elements of such an accounting system and the associated inspection procedure are that:

- The operator identifies, counts or measures the nuclear material in the facility and maintains inventory records, and submits these reports to the IAEA through the State's Systems of Accounting and Control (SSAC)
- IAEA inspectors visit the facility to verify the inventories and inventory changes, to determine the validity of the operator's accounting system and the correctness of the reports made to the IAEA.
- The IAEA inspectors also perform an annual physical inventory verification (PIV) when all available nuclear material is identified and verified.

In any new nuclear facility the application of nuclear material safeguards will have to take into account the accessibility of the nuclear material and the possibilities for tracking the flow of the material through the facility. During the design stage the inspector must try to identify the possible location for measurement and monitoring devices in order to provide the verification possibility. The safeguards inspector must also take into account the expected MBA boundaries and must assure him/herself of the expected flow of the item or nuclear material movement through the facility. The normal route must be capable of being monitored together with possible exit routes in the passage through the facility. Under the integrated safeguards foreseen by the Additional Protocol, inspections may be unannounced or upon short-notice. In addition complementary access may be used.

2.3 Containment and surveillance

Containment and surveillance (C/S) is based on a system of surveillance and/or tamper indicating devices installed by IAEA, or belonging to the operator in shared Use. The application of containment and surveillance can only effectively be applied upon completion of the facility. The safeguards inspectors should take advantage of the containment provided by the physical barriers of the plant and ensure that they are satisfied with their integrity during the construction phases. If there is a need for cabling it is preferable to install the cables during the construction phase so that they can be incorporated and tested into the facility infrastructure. This will not only be more economical in financial terms but will also allow the inspector to witness and verify the cable integrity.

The frequency of surveillance can range from continuous to intermittent sampling, based on the estimated operating time required to accomplish a diversion. Seals of various types are installed by inspectors to maintain continuity of knowledge and insure against unverified opening of possible diversion routes not monitored by cameras.

3. Safeguards by Design process

The Safeguards by Design (SBD) process is a complex multi-disciplinary interactive process, optimizing the purpose and intrinsic features of the facility (scope, process, materials, planning) with safeguards, safety, security, economics and sustainability requirements. Interaction between the Safeguards Inspectorate, the State, and the facility operator is essential during the early stages of the design phase of a new facility for a successful implementation of safeguards. The addition or back fitting of safeguards equipment to existing or new plant is generally not the most efficient procedure and so early input into the plant design in discussion with the designers and future facility operators is valuable.
Six groups of Stake-holders are identified, interacting at various times and in various ways which will be described in the following.

3.1 SBD Stake-holders

Six groups of Stake-holders are hereafter identified for the Safeguards by Design (SBD) process, namely:

- IAEA
- Operators
- Designers/Constructors
- Equipment Suppliers
- Regional and/or State System for Accounting and Control
- The scientific community

Each of these groups have different motivations for supporting the SBD process..
For the IAEA the main expected benefits from SBD would be cost savings, improvement of inspection conditions compared to present standards and finally implementation of more effective and efficient safeguards, which is also the goal of Regional and/or State System for Accounting and Control.
The main motivations for the operator would instead be minimising the impact on the overall cost of the facility and to reduce safeguards intrusiveness during the operation of the plant. The integration of the SBD process with existing processes would avoid construction delays and reduce construction costs caused by the addition, or back-fitting, of safeguards equipment to existing or new but frozen-design plants.
For the same reason, designers should be made aware already at the inception and design phase of the future safeguards requirements such as penetrations, camera views, needs for sealing, potential locations of unattended measurement stations, cabling pre-installation needs and more.
Not less important stake-holders are equipment suppliers and the scientific community, all benefiting from an early-starting and interactive process.

3.2 Design information in SBD process

The above mentioned provision of design information to the Agency is a key issue in the process.
The requirements of INFCIRC 153 include:

- *General arrangement of the facility with reference, to the extent feasible, to the form, location and flow of nuclear material and to the general layout of important items of equipment which use, produce or process nuclear material;*
- *Description of features of the facility relating to material accountancy, containment and surveillance; and*
- *Description of the existing and proposed procedures at the facility for nuclear material accountancy and control, with special reference to material balance areas established by the operator, measurements of flow and procedures for physical inventory taking.*

The timing for the provision of information is a key aspect to address for an efficient SBD process. The identification of the key measurement points is an important factor in understanding the proposed approach and inspection strategy. Details of these points should be communicated to the designers and operators. It is important that the designers are aware, at an early stage, of any space requirements needed by the inspectors for installation of supporting equipment and instruments in order to safeguard the nuclear material inside the facility.

INFIRC 153 states that:
"*…the time limits for the provision of such information in respect of new facilities shall be specified in the Subsidiary Arrangements … as early as possible before nuclear material is introduced into a new facility.*"
This is obviously too late to avoid the need for readjusting a frozen design.

3.3 SBD process timeline

The different SBD stakeholders should interact continuously through the design, construction, operation, and even decommissioning phases of a facility. A comprehensive and interacting SBD process should already begin during the R&D phase, with an exchange of information between the IAEA, the R/SSAC, the operator, and the designer. In any new nuclear facility the application of nuclear material safeguards will have to take into account the accessibility of the nuclear material and the possibilities for following the passage of the material through the facility

A proposed improved interaction timeline could be:

- The IAEA should provide designers with a statement of safeguards requirements as early as possible when plans for a new facility are communicated.
- The R/SSAC, in turn, should provide the IAEA with preliminary design information.
- High level safeguards guidelines specific for the facility type in object, should be available to the designer, for a first concept to be presented to the operator, the R/SSAC and to IAEA.
- Low-level details and requirements should then be addressed at the beginning of the facility design and construction process, specifying the safeguards system performance and test acceptance criteria.

As a result, the development of the safeguards approaches and their elements should ideally match the new facility's milestones, as summarised in Table 1.
This would apply to innovative facilities, but also to so-called evolutionary facilities, still based on existing facilities' design, but with a consistent degree of improvements.
The experience of operating facilities must be used by all parties for the purpose of identifying and compiling the best high level design features and safeguards practices.

4. SBD implementation

Safeguards by Design can be addressed by improving the facility's design and/or improving the techniques by means of which safeguards are implemented. The identification of key measurement locations and the physical boundaries of nuclear material areas will provide invaluable assistance for the implementation of verification measures and containment and surveillance measures.
Design "intrinsic" features, including of course the lay-out of the facility, can facilitate the implementation of "extrinsic measures", i.e. the safeguards approaches we saw above, in ways that will be further developed.
Improving the facility design is a complex multi-attribute exercise because each design feature has a primary goal that can conflict with those of other features. The overall design is thus the result of the complex interaction among all the features, to cope with safety, security, safeguards, as well as economics and sustainability requirements.

Table 1: Safeguards by Design process

Design Phases	R/SSAC	IAEA	Designer and operator
R&D phase	Provide information to IAEA under AP	Best safeguards practices compilation	Facility pre-concept
Pre-Conceptual design	Preliminary design information to IAEA	Safeguards requirements; High level SG guidelines	Preliminary concept
Preliminary design	DIQ	Medium level SG guidelines; Safeguards approach; Detailed SG guidelines; Design Information evaluation	Preliminary design
Final design	Draft facility attachment		
Construction		DIV Safeguards installation	
Commissioning	Final facility attachment	DIV	
Operation		Inspections DIV	

5. Methodologies for SBD

The Safeguards by Design process requires an understanding by designers and operators of proliferation resistance and its underlying principles. Interaction between the Safeguards Inspectorate, the State, and the facility operator is essential during the early stages of the design phase of a new facility and the construction phase for a successful implementation of nuclear material safeguards. Relevant studies and methodologies developed by the Proliferation Resistance and Physical Protection (PR&PP) Working Group of GEN-IV [2],

and IAEA INPRO [3], can be instrumental to the SBD process.
Both methodologies include the concept of safeguardability, defined as “a concept that reflects the degree of ease with which a facility can be put under safeguards” [2] and it could be used in the conceptual and preliminary design phases, as it deals with system’s features and does not require a detailed design.

6. Safeguardability

The issue of how to tackle the problem of the Safeguardability of nuclear energy systems existed since the foundation of the International Atomic Energy Agency, and during the last thirty years at least two different approaches emerged:

- developing new safeguarding techniques and equipment to enhance safeguards effectiveness and efficiency.
- providing guidelines for designers of new systems in order to enhance systems Safeguardability during early design stages.

Its goal is to provide system designers with a list of attributes to be taken into account at very early design stages in order to facilitate the implementation of International Safeguards.
As first iteration, the single features can be looked at and grouped for their relevance to the safeguards components implemented (i.e. NMAC, DIV, C/S) and for their direct relevance to fuel management and reactor operation.

The safeguardability relevance of the features (e.g. extent of access to the core, or type and burn-up of the fuel) can be estimated by means of Utility functions. The overall contribution of the various features is then aggregated by weighed multiplication of the results. Uncertainties should be taken into account, estimating how they propagate through the model.
A list of design attributes and their safeguardability relevance are proposed in [5] and in a more extensively developed model [6].

7. Conclusions

The SBD process is expected to have a positive impact on the implementation of international safeguards and benefit its various stake-holders.
It is important that the IAEA inspectors understand the detailed operations of the facility and the possible diversion routes before they establish a safeguards approach.

It is essential that the safeguards approach is designed sufficiently early so that designers/operators are made aware of the safeguards requirements and the expected verification techniques that be utilised inside the facility so that instruments can be built in or incorporated into the design.

The SBD process relies upon close co-operation between the facility designers and the safeguards authorities during the detailed design phase to ensure that the safeguards requirements are taken into account and to avoid unnecessary modifications when the facility is at an advanced commissioning stage.

A first draft of the SBD Guidelines has been provided by EURATOM to the IAEA, and it is expected that it will be improved also by the contribution of other support programmes.
As an additional contribution, ESARDA (European Safeguards Research and Development Associations) [7] has created a SBD sub-group within its “Implementation of Safeguards” Working Group, which is currently considering SBD guidelines.
As defined by IAEA, further steps should encompass the definition of low level guidelines specific for the various facility types.

References

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

[2] PR&PP Expert Group, Evaluation Methodology for Proliferation Resistance and Physical Protection of Generation IV Nuclear Energy Systems, Revision 5, November 30, 2006 GIF/PRPPWG/2006/005:
http://www.gen-4.org/Technology/horizontal/PRPPEM.pdf

[3] Technical Addendum to Revision 5, January 31, 2007 GIF/PRPPWG/2006/005-A, http://www.gen-4.org/Technology/horizontal/

[4] International Atomic Energy Agency. Guidance for the Application of an Assessment Methodology for Innovative Nuclear Energy Systems, INPRO Manual — Proliferation Resistance Volume 5 of the Final Report of Phase 1 of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), IAEA-TECDOC-1575, October 2007.

[5] G.G.M. Cojazzi, G. Renda, F. Sevini, Proliferation Resistance Characteristics of Advanced Nuclear Energy Systems: a Safeguardability Point of View, ESARDA Bulletin No. 39, Special Issue on Proliferation Resistance, October 2008, pp. Available at: http://esarda2.jrc.it/bulletin/bulletin_39/index.html

[6] G. Renda, Resisting Nuclear Proliferation through design - A systems' Approach to Nuclear Proliferation Resistance Assessment, Ph.D. Thesis, University of Bristol, December 2008

[7] ESARDA web-site, www.esarda.eu