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Results of the INPRO Collaborative Project, "Proliferation Resistance: Acquisition/Diversion Pathway Analysis"

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1. Introduction

Within Phase 2 of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), a Collaborative Project (CP), ROK1 "Proliferation Resistance: Acquisition/Diversion Pathway Analysis (PRADA)" has been carried out from 2007 to 2010, and has been used to develop a methodology for evaluating User Requirement (UR) 4 regarding the multiplicity and robustness of barriers against proliferation. This paper describes the main results of the PRADA project.

2. INPRO Methodology

The INPRO methodology is an internationally validated tool for assessing an innovative nuclear energy system (INS) for its long range sustainability in all key areas, from economics to proliferation resistance to the environment. The INPRO methodology used in the area of proliferation resistance has one Basic Principle (BP) and 5 User Requirements (UR), along with relevant Criteria, Proliferation Indicators, Evaluation Parameters, etc. [1]. The overall objective of PRADA CP was to provide guidance on enhancing proliferation resistance of innovative nuclear energy systems and contribute to strengthening the assessment area of 'proliferation resistance' of the INPRO methodology.

3. Acquisition/Diversion Pathway Analysis

The PRADA project focuses on identifying and analyzing high level pathways for the acquisition or diversion of fissile material for a nuclear weapons program using an assumed diversion scenario. PRADA CP consists of three phases: 1) selection of the prospective pathways, 2) analysis of these pathways, and 3) an assessment of their multiplicity and robustness. The DUPIC (Direct Use of spent PWR fuel In CANDU reactors) fuel cycle was used as a case study to elaborate the metrics and procedure used to evaluate the multiplicity and robustness of barriers against proliferation [2].

The objective of the potential proliferant State was assumed to be the acquirement of nuclear material that could be used for nuclear explosive devices. Once the nuclear material is acquired from a nuclear energy system, the nuclear material will be transported to a clandestine processing facility for the production of weapon-usable material. A strategy that a proliferant State can use to manufacture nuclear weapons is shown in Fig. 1.

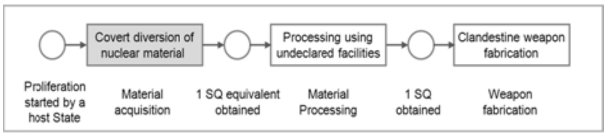

Fig. 1. Proliferation strategy of host State.

The acquisition/diversion pathway analysis of a nuclear energy system should ensure that all possible targets and pathways have been identified and analyzed. Since the pathway analysis should be reproducible for its objectiveness and comprehensiveness, a step-by-step approach was proposed for the acquisition/diversion pathway analysis [3]. This approach was applied to the DUPIC fuel cycle, and the proliferation target in the case study was fresh DUPIC fuel bundle in a fresh fuel storage area.

4. Proliferation Resistance Analysis

In order to evaluate the multiplicity and robustness of barriers against proliferation, the PR characteristics of each segment along the selected pathway, *Diverting Fresh DUPIC Fuel Bundles from the DUPIC Fuel Storage Pool*, were identified and analyzed according to User Requirements 1, 2, and 3 of the INPRO PR methodology [1].

Compliance with User Requirement 1 (UR1), *State's obligations, policies and commitments*, has considerable impact on the PR of an INS. On one hand, it demonstrates a State's compliance with non-proliferation commitments, while on the other hand, it establishes the tools needed to detect non-compliance at the State and INS/facility levels. UR1 has two criteria: criterion 1.1 (CR1.1), Legal Framework, and criterion 1.2 (CR1.2), Institutional Structural Arrangements at the State level. CR1.1 asks the State to establish a sufficient legal framework addressing international non-proliferation, i.e., ensuring the adequacy of the State's commitment, obligations, and policies regarding non-proliferation. CR1.2 determines if the implementation is adequate to fulfill the international standards in the non-proliferation regime. UR1 also addresses the capability of the IAEA to detect undeclared nuclear material and activities.

User Requirement 2 states that the INS should have low attractiveness of nuclear material and technology for use in a nuclear weapons program. This user requirement refers to key proliferation barriers related to material and technology characteristics at the facility level. The role of the INPRO assessor is to determine whether an INS has achieved a level of attractiveness that is acceptably low by assessing the corresponding criteria. The attractiveness of nuclear material is determined by two intrinsic features: the conversion time and the total mass needed to achieve 1 SQ. The attractiveness of nuclear material increases with shorter conversion time of the acquired material and by smaller mass of nuclear material needed to form 1 SQ.

User Requirement 3 asks for the reasonable difficulty and detectability in the diversion of nuclear material, and is to be fulfilled by the technology holder (developer) at the facility level. UR3 must be seen in the context of UR1, which provides the necessary framework to implement safeguards. The evaluation parameters of UR3 and the results in the assessment matrix table should be related to a specific acquisition pathway and material. All assessments concerning barriers and diversion difficulty should be related to specific proliferator actions. The specific equipment, containment and surveillance (C/S) measures, etc. involved should be addressed in the evaluation of UR3 for specific acquisition pathways, and therefore this UR is associated with 'Safeguards by Design'.

User Requirement 4 asks for the INS to incorporate multiple PR features and measures, to be implemented by the technology developers in cooperation with PR experts. INPRO has defined two criteria for UR4: multiplicity (defence in depth) and robustness of barriers. UR4 can be assessed at the State level, the INS level, and the facility level, including facility specific pathways, although different issues are involved. Some of the characteristics of nuclear material and technology discussed in UR2, and detectability and difficulty of diversion in UR3, are integral elements in assessing UR4. In addition, UR1 provides State-level barriers against proliferation, the necessary framework for implementing safeguards, and in this context, the evaluation of UR3. The multiplicity of proliferation barriers should be considered together with their robustness in assessing UR4.

The acceptance limit for the multiplicity requirement of UR4 is that all plausible acquisition/diversion pathways of the INS (composed of several sequential segments) are or can be covered by extrinsic measures at the facility level and by intrinsic features compatible with other design requirements. The robustness of proliferation barriers in the context of INPRO PR methodology describes the effectiveness of acquisition pathway barriers. These are a measure of the difficulty of defeating proliferation barriers in terms of time and effort. Robustness is not a function of the number of barriers, or of their individual characteristics, but is an integrated value of the whole. For example, the difficulty in material handling, if not supplemented by safeguards measures, would have a very minor effect on the facility-level diversion compared to the diversion difficulty and detectability barriers. A State proliferator would have unrestricted access to the entire nuclear facility and the equipment designed for handling such type of nuclear material. Therefore, as a result of the PRADA project it has been concluded that the robustness of proliferation barriers is not a function of the number of barriers or of their individual characteristics but is an integrated function of the barriers described in UR1, UR2 and UR3, and is measured by determining whether the safeguards goals can be met. However, it should not be construed as implying that proliferation using a system and its material for which the safeguards goals can be met is impossible (i.e., the system is proliferation-proof). It has also been concluded that the assessment should be performed at three levels, the State level, INS level and facility level.

A successful evaluation of the robustness of barriers identified in UR4 requires sufficient information on the process and design information of the INS, which will become available for an INS only as its design progresses.

The cost of incorporating additional intrinsic features and extrinsic measures into an INS that are required by UR4 to provide or improve PR could be excessively high. Therefore, UR4 leads to User Requirement 5, optimization of the combination of intrinsic features and extrinsic measures in the design/engineering phase to provide cost-efficient PR.

4. Conclusions

The PRADA project made recommendations for assessing the multiplicity and robustness of barriers against proliferation, including institutional, material, and technical barriers as well as barriers resulting from the implementation of international safeguards. The multiplicity of barriers was demonstrated using a proliferation barrier analysis. It was also shown that barriers against PR specified in UR1, UR2, and UR3 are not independent, and that in addition, the strength of barriers against proliferation might depend on the State's capabilities. The main concern in UR4 was to demonstrate the robustness of barriers in relation to the State's capability and to show a way of how to optimize the proliferation robustness.

REFERENCES

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