An idea for assessment of proliferation resistance effects under the integrated safeguards

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Discussion in INPRO

- The final draft document of INPRO shows the definition of proliferation resistance.
- This definition and the accompanying discussion provide the basis for assessing proliferation resistance through two technical metrics.

Definition of impedibility

- The first is the ***impedibility*** against the diversion of declared nuclear materials and the misuse of the declared process.
- ***Impedibility*** is related to intrinsic proliferation resistance features of the subject process including the limitation of any possible misuse.

Definition of safeguardability

- The second is ***safeguardability*** against diversion and misuse.
- ***Safeguardability*** includes the safeguards approach and associated measures to be applied to the processes as one of the extrinsic proliferation resistance measures.
- Of course, external institutional aspects support effective and efficient application of safeguards.

Features of impedibility

- ***Impedibility*** against the diversion of declared nuclear materials and the misuse of declared proliferation resistant processes includes technical features that mitigate against diversion and misuse.
- The act of diversion involves unauthorized removals of nuclear material from peaceful uses and subsequent actions to place the diverted material into an appropriate form for the component of an explosive device.

Features of impedibility

- The level of ***impedibility*** against diversion is the level of difficulties of unauthorized removals and for any subsequent processing activities.
- In case of the PUREX process, the intrinsic level of difficulties is low.
- The low ***impedibility*** of the PUREX process results in extensive safeguards requirements including continuous inspector presence and intensive verifications.

Features of safeguardability

- ***Safeguardability*** reflects the limits of accountancy of the amounts of declared nuclear materials and the intensity of verification.
- ***Safeguardability*** is the availability of material accountancy and C/S systems sufficient to assure that the material is adequately accounted for and that none has gone missing.
- Obviously, verification activities with quantitative measures are included in it.

Conditions of Integrated safeguards

- In the discussion of integrated safeguards, the IAEA emphasized that through the application of the supporting guidelines and model approaches developed for integrated safeguards, strengthened safeguarding approach will be used.
- The approach will take into account specific features and characteristics of the State and its nuclear fuel cycle with several strengthened measures to assure the absence of undeclared nuclear activities and materials.

Conditions of Integrated safeguards

- Under the strengthened conditions of the safeguards toward the detection of misuses and undeclared nuclear activities, the degree of proliferation resistance can be assessed through the evaluation of two independent technical aspects i.e., the ***impedibility*** and the ***safeguardability***.

Elements of impedibility and safeguardability

- Rigid quantification of the levels of both technical aspects may not be possible, but the level of proliferation resistance can be assessed qualitatively.

"**Impedibility**"	"**Safeguardability**"
Difficulties in •Acquisition of NM •Diversion of NM •Direct use for NW •Conversion to DUM •Misuse of facility •Modification of facility	Detection capability for •Acquisition of NM •Misuse of facility •Modification of facility •Undeclared NM production •Undeclared nuclear activity

Assessment factors of impedibility

- The impedibility indicates the proliferation resistance feature that the subject facility originally possesses.
- The impedibility is composed of the impedible factors in the acquisition paths of weapon usable materials and associated technical impedible elements concerned with facility intrinsic features.
- The impedible factors relevant to the acquisition paths and technical impedible elements are shown in the table-1.

Table-1 The impedible factors relevant to the acquisition paths and technical impedible elements

Scenarios to acquire the UDU materials	Impedible factors	Technical Impedible elements	The reference points for technical judgments	The degree of technical impedible elements					
				5≥	4≥	3≥	2≥	1≥	Subtotal
Cases to need conversion process for produce the UDU materials	1.Obstacles to the unauthorized acquisition ・Significant quantity ・Drawing path way ・Radiation protection	- Critical mass - Radiation dose rate - Bulk of materials to 1SQ - Concealment Alternatives - Equipment to draw out	Possible quantity to draw out under un-criticality Radiation protections e.g., Cells, Containers Density of the materials Chemical/Physical features, Radiation spectrum Physical forms of the materials (Solid/Liquid)						Σ1
	2.Obstacles to the unauthorized movements ・Ways of movements ・Radiation protection	- Bulk of materials to 1SQ - Radiation dose rate - Heat generation rate - Transfer container	Size of container Radiation protections e.g., Cells, Containers Configuration for heat release Weight and material of container						Σ2
	3.Impossibilities to use of a explosive devices ・Conditions of super-criticality ・Designs of a explosive devices	- Mass and types of impurities - Isotope factors of fissile - Spontaneous neutron rate - Bulk of materials to 1SQ - Radiation dose rate - Heat generation rate	Necessity of purification Quality of fissile material Influences from spontaneous neutron generation Designs of a explosive devices The same above The same above						Σ3
	4.Impossibilities to convert to the UDU materials ・Convert to plutonium nitrate or plutonium oxide ・Purification	- Mass and types of impurities - Bulk of materials to 1SQ - Processes to be needed - Times to be needed - Radiation dose rate	Types of the necessary processes Scales of the necessary processes Specified technologies and equipment Timely detection risk of undeclared construction Radiation protections e.g., Cells, Containers						Σ4
Cases to produce the UDU materials at the subject facility	5.Difficulties to modify the operation parameter ・Possibilities of misuse	- Operation risk and time - Additional conditions - Equipment to draw out - Bulk of materials to 1SQ - Concealment Alternatives	Technical possibilities and procedures The same above Additional equipment to the original process Density of the materials Modified operation parameter						Σ5
	6. Difficulties to modify the facility designs ・Attractiveness of modification	- Complexity of modification - Cost for modification - Influence to the safety - Times to be needed - Scales of the facility - Concealment Alternatives	Modification of designs and operation conditions Total costs to be needed Criticality conditions and radiation dose rate Risks of detection by the DIV and the CA Grade of modification to be needed Modified facility designs						Σ6
Total Aggregation									Σtotal

Assessment factors of safeguardability

- The safeguardability indicates qualitative and quantitative level of safeguards activities to be carried out at the subject facility by the inspectorate.
- The introduction of integrated safeguards could be considered the status of the compliance with various international commitments.
- The table-2 shows the safeguardable elements with the reference points.

Table-2 Safeguardable elements with reference points

Agreement	Global conclusions	Verification requirement	Items to be detected	Safeguardable elements	The reference points to be considered	Safeguards levels to be applied					
						5≥	4≥	3≥	2≥	1≥	Subtotal
Comprehensive safeguards agreement and its additional protocol	Yes: Integrated safeguards	Correctness of declaration by the State	Detections of unauthorized acquisition and movements of the UDU materials	- Material accountancy (MA) - Containment and surveillance(C/S) - Routine Inspection - Information analysis -Environmental sampling (ES)	- An appropriate cost effective MA system considering facility features - Appropriate applications considering facility design conditions - Random inspection without notifications - Analysis of boarder information - Selection of appropriate sampling places and carry out						Σ1
			Detection of misuse - Modification of operation parameter and designs	-Continuous Design information verification	- Periodical DIE of significant parameter and designs with DIV						Σ2
		Completeness of declaration by the State	Detection of undeclared activities including undeclared production of the UDU materials	- Complementary access	- CA with 24 hours advanced notice - CA with 2 hours advanced notice in conjunction with inspection and DIV - CA to any location specified by the IAEA to carry out ES with 24 H advanced notice						Σ3
	No: Strengthened safeguards	Correctness of declaration by the State	Detection of unauthorized acquisition and movements of the UDU materials	- Material accountancy (MA) - Containment and surveillance(C/S) - Inspection - Information analysis -Environmental sampling(ES)	- An accurate MA according to the international target and standard - Appropriate applications considering facility designs accr0ding to SG Criteria - Timely detection of 1SQ diversion with high detection probability - Analysis of boarder information - Selection of appropriate sampling places and carry out						Σ1
			Detection of misuse - Modification of operation parameter and designs	-Continuous Design information verification	- Periodical DIE of significant parameter and designs with DIV						Σ2
		Completeness of declaration by the State	Detection of undeclared activities including undeclared production of the UDU materials	- Complementary access	- CA with 24 hours advanced notice - CA with 2 hours advanced notice in conjunction with inspection and DIV - CA to any location specified by the IAEA to carry out ES with 24 H advanced notice						Σ3
Total aggregation											Σ total

Assignment of grade expressions

- Each technical element in the table-1 and the table-2 is marked by five grade expressions from 1 to 5.
- The highest degree is assigned as point 5. The lowest degree is assigned as point 1.
- The degree will be decided by the technical judgment in consideration of the reference points.

Aggregate approach

- The marked points of each element are aggregated according to formula mentioned below.

$$\Sigma\, m = (N_5 \times 5 + N_4 \times 4 + N_3 \times 3 + N_2 \times 2 + N_1 \times 1) / \{(N_1 + N_2 + N_3 + N_4 + N_5) \times 5\}$$

- *Italic number from 1 to 5* in the formula shows the importance weight values of each element. Larger number means higher impedibility and safeguardability.

Aggregate approach

- Assigned number to be marked at each element should be an integer such as points of *1,2,3,4* and *5*.
- Nn (n= 1,2··,5) means numbers of element composed of obstacles or impossibilities at individual cell.
- Aggregated number shown as Σm means the degrees of impedibility or safeguardability in each cell.

Aggregate approach

- The total impedibility is aggregated by the formula mentioned below.

$$\Sigma\,\textbf{total, impedibility} = \Sigma\, m_1 + \Sigma\, m_2 + \Sigma\, m_3 + \Sigma\, m_4 + \Sigma\, m_5 + \Sigma\, m_6$$

- The total safeguardability is aggregated by the formula mentioned below.

$$\Sigma\,\textbf{total, safeguardability} = \Sigma\, m_1 + \Sigma\, m_2 + \Sigma\, m_3$$

- Each $\Sigma\,\textbf{total}$ is located at X-Y coordinate, respectively.
- Examples of aggregation results of facility types is shown in next.

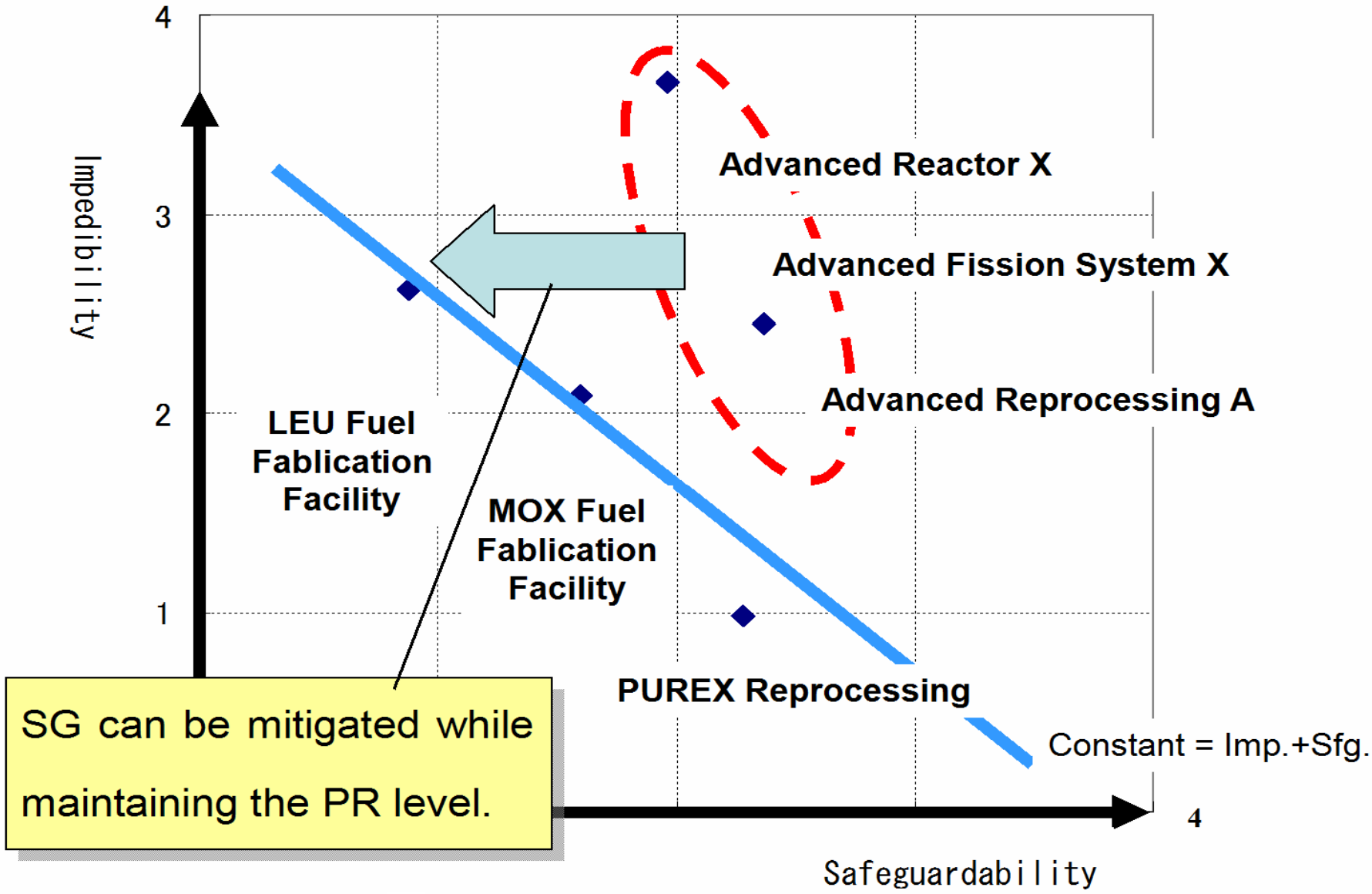

Figure Examples of aggregation of typical types of facility