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P2. Overview of PSA applications

Workshop on Application of Level 1 Probabilistic Safety Assessment

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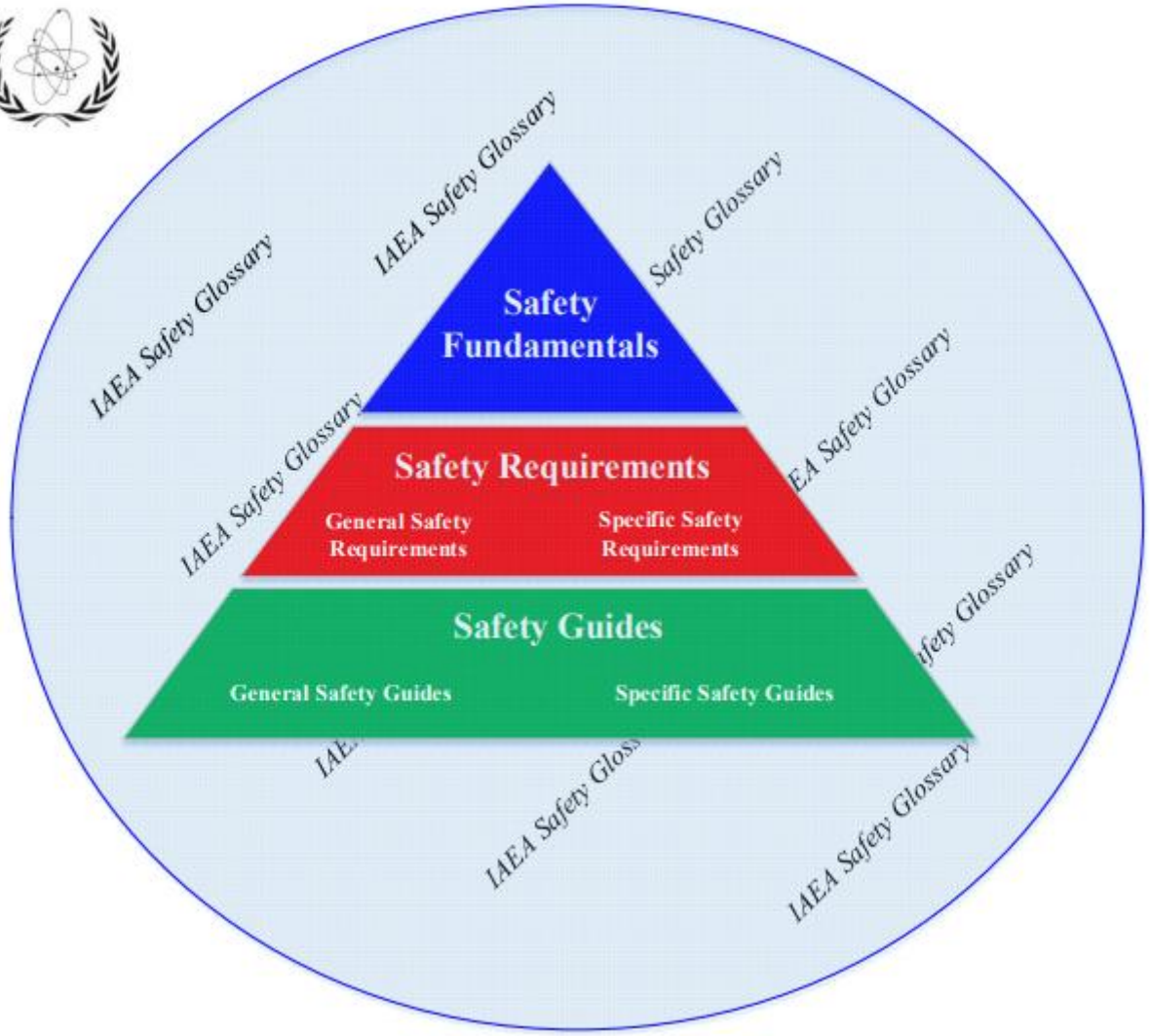
Outline of Presentation

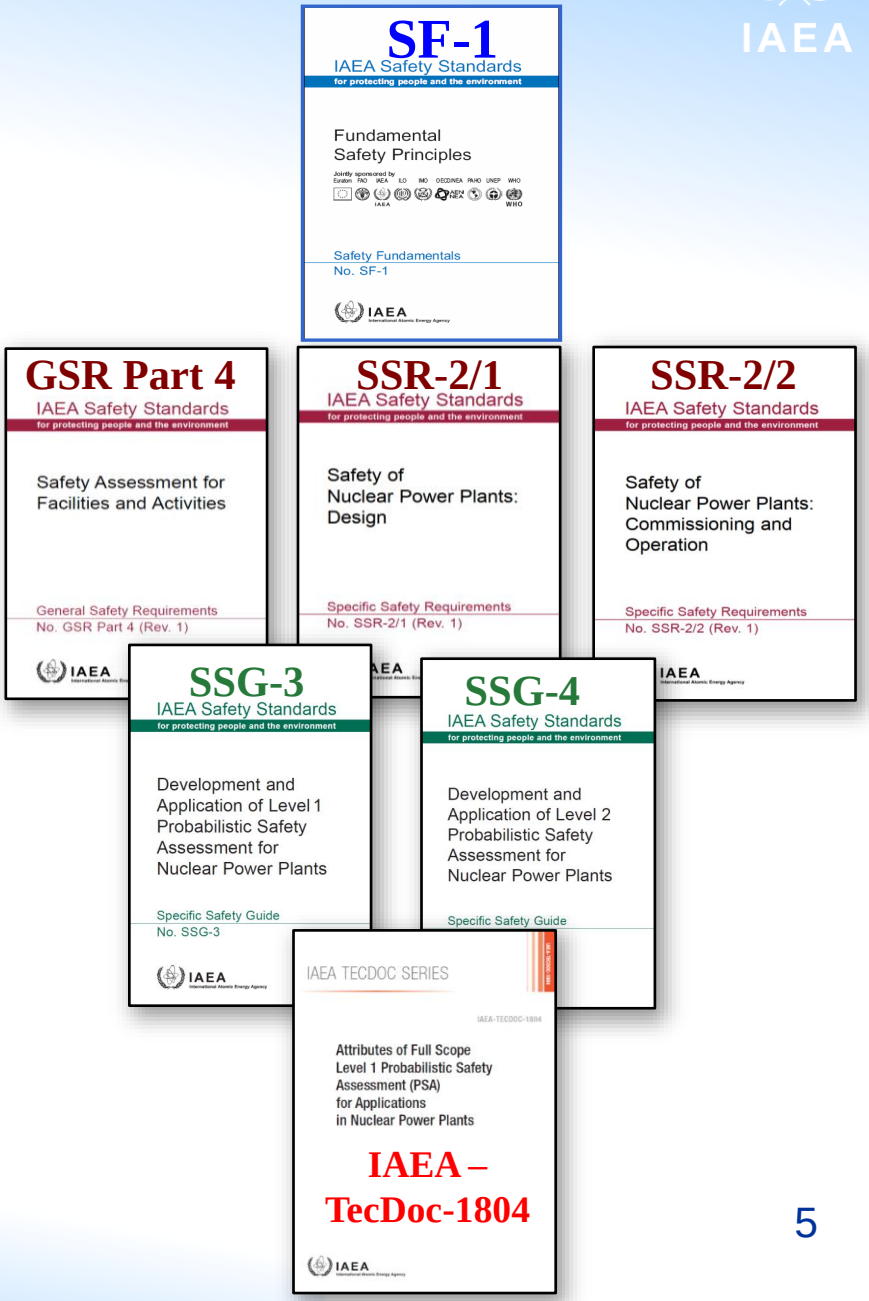
- PSA applications in IAEA publications
- Taxonomy of PSA applications
- Brief overview of PSA applications
- Quality of PSA models for applications

PSA applications in IAEA publications

Hierarchy of IAEA Safety Standards



PSA applications in IAEA publications



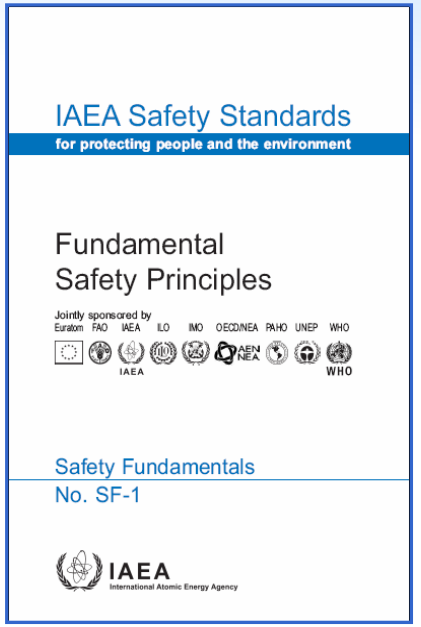
Relevant Statements from IAEA Safety Standards

The fundamental safety objective is

to protect people and the environment from harmful effects of ionizing radiation

Principle 6: Limitation of risks to individuals

*"Measures for controlling radiation risks must ensure that no individual bears an **unacceptable risk of harm**"*



Implications:

1) Risk associated with nuclear installations needs to be assessed

2) Guidance (criteria) for 'unacceptable risk' need to be established

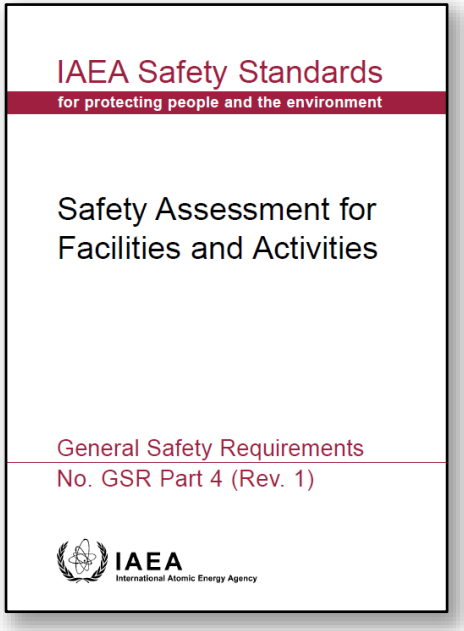
3) Relevant measures (design features and procedures) provided

PSA applications in IAEA publications: Safety Requirements on Safety Assessment (1/2)

- Safety assessment shall include a safety analysis, which consists of a set of different quantitative analyses for evaluating and assessing challenges to safety by means of **deterministic** and also **probabilistic** methods
- **Deterministic** and **probabilistic** approaches have to complement one another

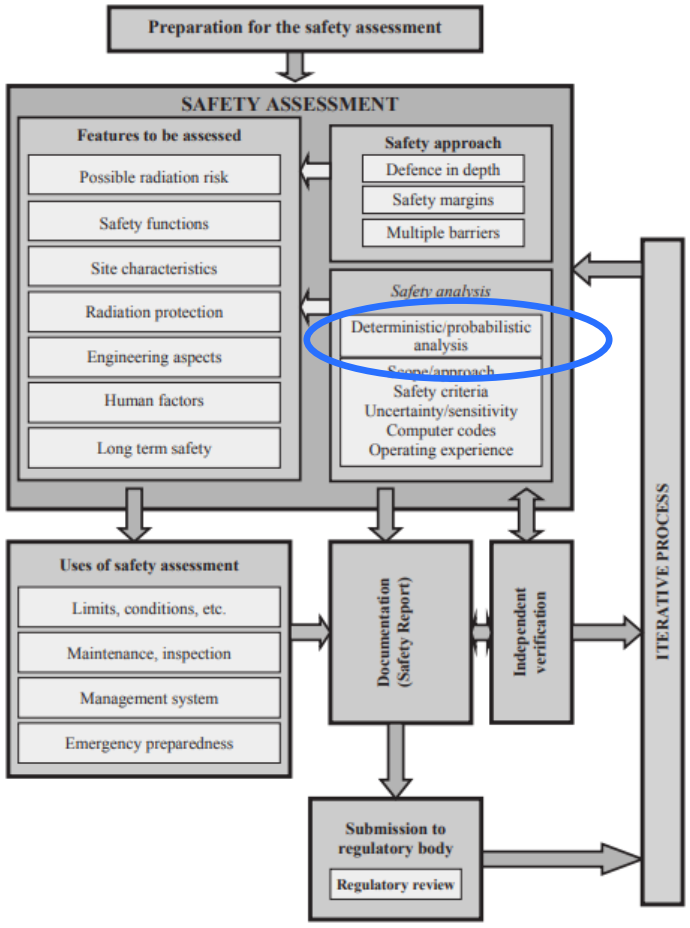
- PSA to determine all significant contributing factors to the radiation risks arising from NPP
- PSA insights: system performance, reliability, interactions and weaknesses in the design, the application of defence-in-depth, and risks, that it may not be possible to derive from a deterministic analysis.

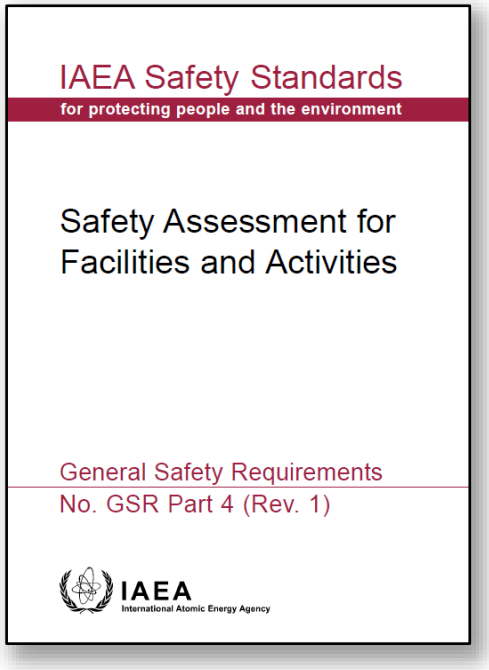
The results of the safety assessment shall be used to make decisions in an integrated, risk informed approach, by means of which the results and insights from the deterministic and probabilistic assessments and any other requirements are combined in making decisions on safety matters in relation to the facility or activity.



PSA applications in IAEA publications:
Safety Requirements on Safety Assessment (2/2)

Overview of Safety Assessment Process

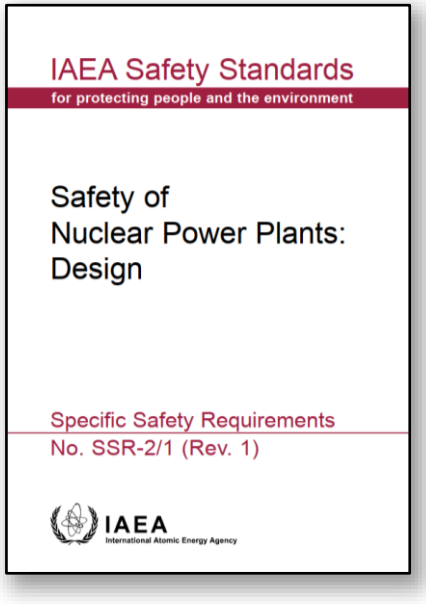




PSA applications in IAEA publications: Safety Requirements on NPP Design

PSA shall be carried out throughout the design process to ensure that all safety requirements are met throughout all stages of NPP lifetime

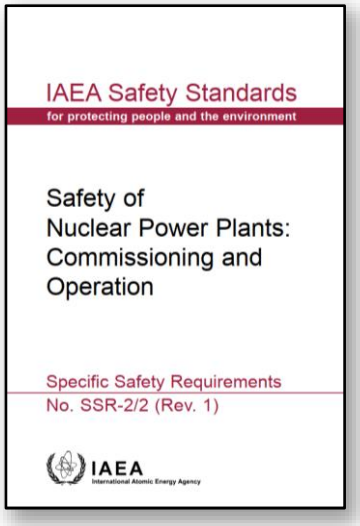
- PSA shall be used in NPP design to:
  - Establishing balanced NPP design
  - Implement measures to avoid cliff-edge effect
  - Compare with risk criteria (probabilistic safety goals)
- PSA is used also for selection postulated IEs & DEC scenarios to be considered in NPP design (identification of input for deterministic analyses)
- PSA is used also for supporting NPP system, structures and components (SSCs) safety classification



PSA applications in IAEA publications:
Safety Requirements on NPP Commissioning and Operation

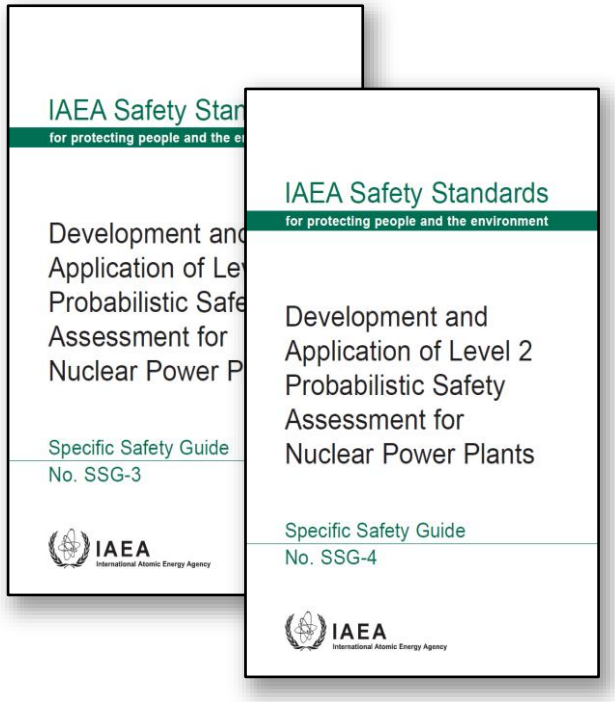
- **To complement deterministic safety assessment (inter alia while conducting periodic safety review)**

- PSA is to be used to determine frequency of maintenance, testing, surveillance and inspection of individual SSCs
- PSA shall be used, as appropriate, to demonstrate that the risks are not significantly increased due to maintenance activities
- Quality of PSA models shall be ensured for PSA applications



PSA applications in IAEA publications: Safety Standards on Level-1&2 PSA

- **Various PSA applications are presented in Section 10 of SSG-3 and Section 8 of SSG-4**
- **In PSA applications described in SSG-3 & SSG-4 insights from PSA should be used as part of Integrated Risk informed decision making (IRIDM) process considering:**
  - Mandatory requirements
  - Insights from deterministic considerations (e.g. on Defence in Depth)
  - other applicable information (e.g. cost–benefit analysis, inspection findings, operating experience, doses to workers)



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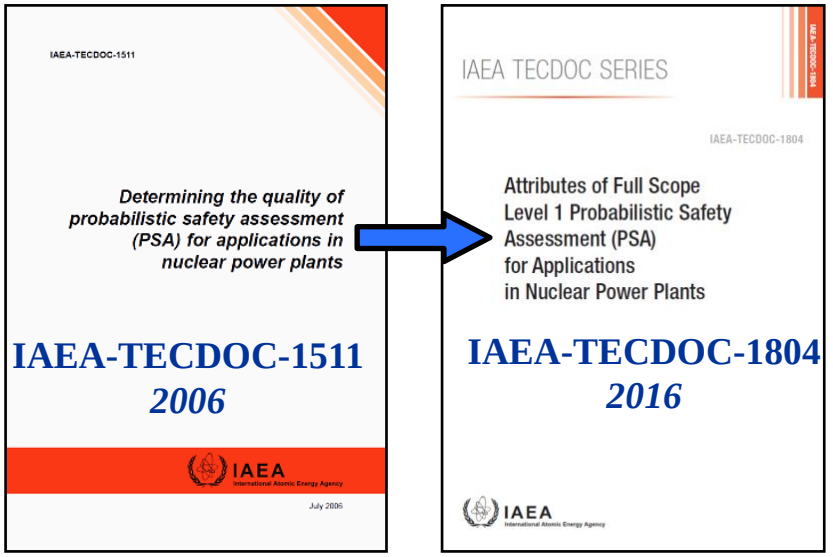
Attributes to full-scope L1 PSA for Applications in Nuclear Power Plants

- **Provides an approach and detailed guidance for achieving the technical quality of PSA needed to support various PSA applications**
- **Covers a full-scope Level-1 PSA for NPPs**

- Provides comprehensive list of PSA Applications with brief description of each PSA application
- **6** categories and about **40** specific applications



Taxonomy of PSA applications

- **Safety assessment: to assess the overall safety of the plant and to develop an understanding of the main contributing to risk (understanding risk profile)**
- **Design stage: to provide support for design improvements during design and pre-operational stage**
- **NPP operation: to provide support for plant daily operation (excluding permanent changes to design or operation practice)**
- **Permanent changes to operating NPP: to assess the safety significance of proposed permanent changes to the plant SSCs or operating procedures (help for Decision Making)**
- **Oversight activities: to support plant performance monitoring (both regulatory and industry)**
- **Evaluation of safety issues: risk significance**

Brief description of PSA applications

Specific PSA applications

Application Category	Application Group	Specific Application
1. SAFETY ASSESSMENT	1.1. SAFETY ASSESSMENT	1.1. Assessment of the overall plant safety 1.2. Periodic safety review 1.3. Analysis of the degree of defence in depth and safety margin against beyond design basis site hazards, including correlated site hazards
2. DESIGN STAGE	1.2. DESIGN STAGE	2.1. Application of PSA to support decisions made during the NPP design (plant under design) 2.2. Licensing of design 2.3. Optimization of protection against hazard events (e.g. fires, floods) and common cause failures, including consideration of correlated site hazards and hazard-induced fires and floods 2.4. Establishment of equipment reliability targets for manufacturers 2.5. Identification of R&D which are necessary to support the design 2.6. Development operator procedures and training programmes and support for Human Factors Engineering

Specific PSA applications

3. NPP OPERATION	3.1. NPP maintenance	3.1.1. Maintenance programme optimization 3.1.2. Risk informed house keeping 3.1.3. Risk informed support for plant ageing management programme 3.1.4. Risk informed on-line maintenance 3.1.5. Plant outage management
	3.2. Accident mitigation and emergency planning	3.2.1. Development and improvement of the emergency operating procedures 3.2.2. Support for NPP accident management (severe accident prevention, severe accident mitigation) 3.2.3. Support for NPP emergency planning
	3.3. Personnel training	3.3.1. Improvement of operator training programme 3.3.2. Improvement of maintenance personnel training programme 3.3.3. Improvement of plant management training programme
	3.4. Risk based configuration control/ Risk monitors	3.4.1. Configuration planning (e.g. support for plant maintenance and test activities) 3.4.2. Real time configuration assessment and control (response to emerging conditions) 3.4.3. Exemptions to TS and justification for continued operation 3.4.4. Dynamic risk informed TS

Specific PSA applications

4. PERMANENT CHANGES TO THE OPERATING PLANT	4.1. Plant changes	4.1.1. NPP upgrades, backfitting activities and plant modifications 4.1.2. Life time extension
	4.2. Technical specification changes	4.2.1. Determination and evaluation of changes to allowed outage time and changes to required TS actions 4.2.2. Risk informed optimization of TS
		4.2.3. Determination and evaluation of changes to surveillance test intervals 4.2.4. Risk informed surveillance programme 4.2.5. Risk informed in-service inspections (RI-ISI)
	4.3. Establishment of graded QA programme for SSC	4.3.1. Categorization of SSC for equipment risk significance evaluation 4.3.2. Evaluation of risk impact of changes to quality requirements
	4.4. Risk informed special site protection measures	4.4.1. Risk informed fire protection 4.4.2. Risk informed internal flood protection 4.4.3. Risk informed defence in depth for individual and correlated site hazards

Specific PSA applications

5. OVERSIGHT ACTIVITIES	5.1. Performance monitoring	5.1.1. Planning and prioritization of inspection activities (regulatory and industry) 5.1.2. Long term risk based performance indicators 5.1.3. Short term risk based performance indicators
	5.2. Performance assessment	5.2.1. Assessment of inspection findings 5.2.2. Evaluation and rating of operational events
6. EVALUATION OF SAFETY ISSUES	6.1. Risk evaluation	6.1.1. Risk evaluation of corrective measures 6.1.2. Risk evaluation to identify and rank safety issues 6.1.3. Assessment of the safety importance of deviations between an existing plant design and updated/revised deterministic design rules or new information about the site hazards. 6.1.4. Assessment of the significant of overall site risk for multiunit accidents 6.1.5. Assessment of the significant of overall site risk from all radioactive sources
	6.2. Regulatory decisions	6.2.1. Long term regulatory decisions 6.2.2. Interim regulatory decisions

Discussion on PSA applications

- **Further discussion on PSA applications is provided by the six categories and groups (where applicable) mentioned earlier**
- **The following aspects will be highlighted to characterize PSA applications:**
  - **Main Contents / goals of the application**
  - **Notes on the Use of PSA to support the application**

Category 1. Safety assessment

1) Assessment of the Overall Plant Safety

2) Periodical Safety Review

Main contents:

- Identification and ranking of important design and operational features
- Identification and ranking of dominant accident sequences, systems, components, human interactions and dependencies important for safety
- Comparison of the results against Safety goals

Use of PSA:

- Risk contributors and importance information is used to develop risk insights

Category 2. Design evaluation

Risk-informed support for decisions made during NPP design

Main contents:

- Identification of design weaknesses and effective areas for improvement in view of plant risk
- Investigation of design options
- Development of reliability targets for SSCs
- Risk significance of deviation from revised deterministic rules

Use of PSA:

- Additional assumptions are needed (lack of design details)
- Uncertainties are larger than for as-built plant

Category 3.1. NPP Operation:
NPP Maintenance

1) **Maintenance program optimization**
2) **Risk informed support for plant ageing management program**

Main Contents:

- **Assessment, optimization and establishment of maintenance plans and procedures in view of plant risk**
- **Modelling of aging effects in PSA and identification of the ageing vulnerabilities among SSCs**

Use of PSA:

- **PSA model should be capable to include aging phenomena and component lifetime considerations**
- **PSA results can be used to**
  - **Optimize maintenance and ageing management programs**

Category 3.2. NPP Operation:
Accident Mitigation and Emergency Planning

1) Development and improvement of EOPs and SAMGs
2) Support for accident management and emergency planning

Main Contents:

- Systematic assessment of plant vulnerabilities used to establish the EOPs, SAMGs and emergency planning

Use of PSA:

- L2 PSA is required to address severe accident mitigation strategies,
- Prioritize procedural changes
- Understand accident progression and success strategies

Category 3.3. NPP Operation:
Personnel Training

1) Improvement of operator training program
2) Improvement of maintenance personnel training program
3) Improvement of plant management training program

Main Contents:

- Improvement of operator and maintenance staff training programs based on insights and information from the PSA
- Providing plant management with the integral understanding of the techniques, applications and implications of PSA

Use of PSA:

- **L1 PSA** covering all operating and shutdown modes and both internal and external plant hazards is required
- PSA results can be used to focus on potential risk significant accident sequences, operator actions, maintenance activities

Category 3.4 NPP Operation:
Risk-based Configuration Control / Risk Monitors

1) Configuration planning (e.g., support for plant maintenance/tests)
2) Real time configuration assessment and control
3) Exemptions to TS and justification for continued operation

Main Contents:

- The reduction of risk peaks and the control of the cumulative or average risk (e.g., Risk Monitor)

Use of PSA:

- Can provide useful support to TS exemption justifications
  - The purpose of TS framework is to keep plant features within the licensing basis

Category 4.1. Permanent Changes to the Operating Plant: *Plant Changes*

1) NPP upgrades and plant modifications

2) Life time extension

Main Contents:

- **Identification of weaknesses and effective areas for improvement in plants design and operational features**
- **Providing additional information for regulators while licensing the lifetime extension**

Use of PSA:

- **Change in CDF used to justify acceptable risk impacts and to determine risk significance**
- **Involves modelling of aging effects in PSA**

Category 4.2. Permanent changes to the operating plant: *TechSpec Changes*

1) Determination and evaluation of changes to AOTs
2) Risk informed optimisation of TS
3) Determination and evaluation of changes to STI
4) Risk informed in-service testing (IST)
5) Risk informed in-service inspections (ISI)

Main Contents:

- Optimization of the STIs vs impact on equipment reliability
- Re-evaluation of required actions in TS based on risk
- Optimization of AOT period for each SSC
- Support the IST programme vs relative risk significance
- Ranking the elements for inspection

Use of PSA:

- To estimate the risk significance of the changes in TS

Category 4.3 Permanent changes to the operating plant: *Graded QA*

1) Equipment risk significance evaluation

2) Evaluation of risk impact of changes to QA requirements

Main Contents:

- **Determination of the relative safety significance of plant equipment**

Use of PSA:

- **Risk importance measures of affected SSCs (e.g. F-V, RAW) are used to classify the risk and safety significance of SSCs**
- **Change in risk metrics (ΔCDF, ΔLERF) are used to determine the risk significance and risk acceptability of the proposed change**

Category 5.1. Oversight Activities: *Performance Monitoring*

1) Planning and prioritization of inspection activities
2) Long-term risk-based performance indicators
3) Short-term risk based performance indicators

Main Contents:

- Regulatory and industry inspections on risk significant issues and equipment
- Monitoring plant behaviour in order to update the calculated average CDF

Use of PSA:

- PSA provides information on changes in CDF due to plant events and risk associated with planned activities
- The PSA results can be used to determine the appropriate set of performance indicators

Category 5.2. Oversight Activities: *Performance Assessment*

1) Assessment of inspection findings

2) Evaluation and rating of operational events

Main Contents: Self-explanatory

Use of PSA:

- **Estimation of risk-significance associated with inspection findings**
- **PSA based extrapolation of operational events to accident scenarios with serious consequences**
  - **Can provide an estimate, in terms of a conditional probability, of the available margin for an accident with unacceptable consequences**
  - **The PSA model must be capable of evaluating the appropriate impacts assessed for the event**

Category 6.1 Evaluation of Safety Issues: *Risk Evaluation*

1) Risk evaluation to identify and rank safety issues
2) Risk evaluation of corrective measures

Main Contents:

- Identification or evaluation of risk-significance of the plant specific and generic safety issues
- Determination of the risk-effective corrective measures

Use of PSA:

- Based on PSA insights corrective measures regarding safety issues are developed
  - Change in risk metrics (ΔCDF, ΔLERF) are used to determine the risk significance and risk acceptability of the proposed change based on risk characterization
- PSA is used for evaluating the relative importance of existing and new safety issues
  - Contributors to risk and risk importance measures are used to identify and rank safety issues

Category 6.2 Evaluation of Safety Issues: *Regulatory Decisions*

1) Long-term regulatory decisions
2) Interim regulatory decisions

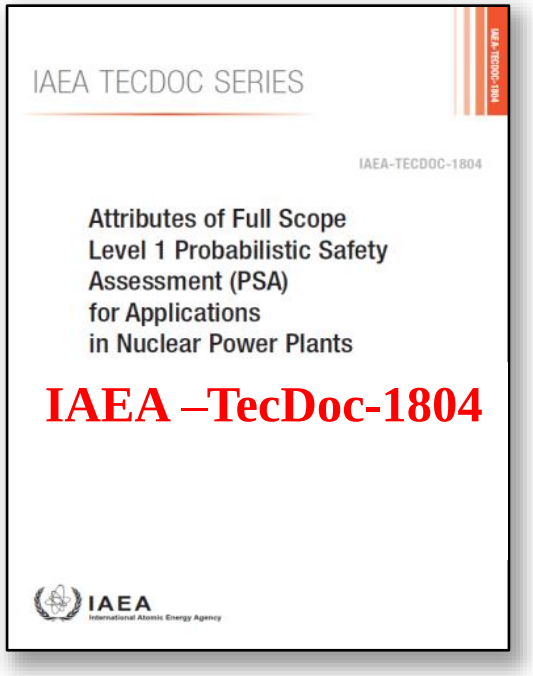
Main Contents:

- Maintaining or reducing risk level

Use of PSA:

- to guide long term prioritization of regulatory objectives and requirements, and of related safety research
- to alleviate a regulatory concern, while longer term solutions can be evaluated
- Issues that typically require an interim decision
  - Need for regulatory action in response to an event
  - One-time exemptions from TS
  - Temporary modifications to hardware or procedures

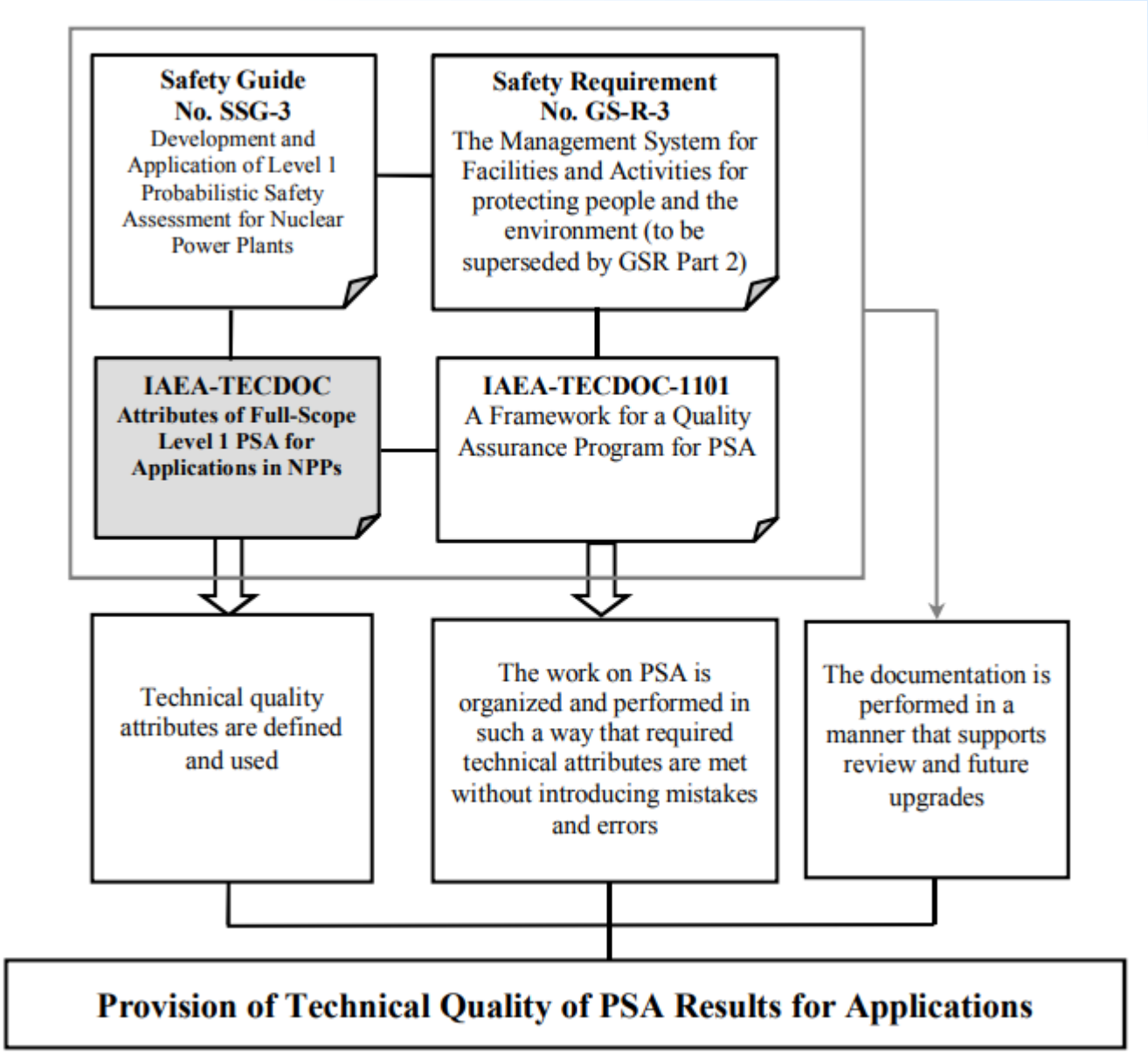
Quality of PSA models for PSA applications



PSA quality ↔ PSA applications

- PSA applications and RIDM require that PSAs used to support those applications have certain characteristics:
  - Scope;
  - Degree of detail;
  - Technical adequacy of the modelling;
  - Capability and flexibility,
  - Quality and type of the data used,
  - Assumptions made in modelling important aspects
- Features of a PSA that are necessary to support specific applications vary with the application
- Need for a basis for judging the technical quality of the PSA used to support an application

Framework of PSA technical quality



PSA elements and associated abbreviations

1.	Plant Operational States Analysis	OS
2.	Hazards Events Analysis	HE
3.	Initiating Events Analysis	IE
4.	Accident Sequence Analysis	AS
5.	Success Criteria Formulation and Supporting Analysis	SC
6.	Systems Analysis	SY
7.	Human Reliability Analysis	HR
8.	Data Analysis	DA
9.	Dependent Failures Analysis	DF
10.	Model Integration and Risk Metric Frequency Quantification	MQ
11.	Results Analysis and Interpretation	RI
12	Maintenance and Upgrade of the PSA	MU

Quality of Level 1 PSA: Attributes

TABLE 7.2-B ATTRIBUTES FOR AS ANALYSIS: TASK AS-B 'DEFINITION OF SUCCESS AND NON-SUCCESS END STATES AND KEY SAFETY FUNCTIONS'

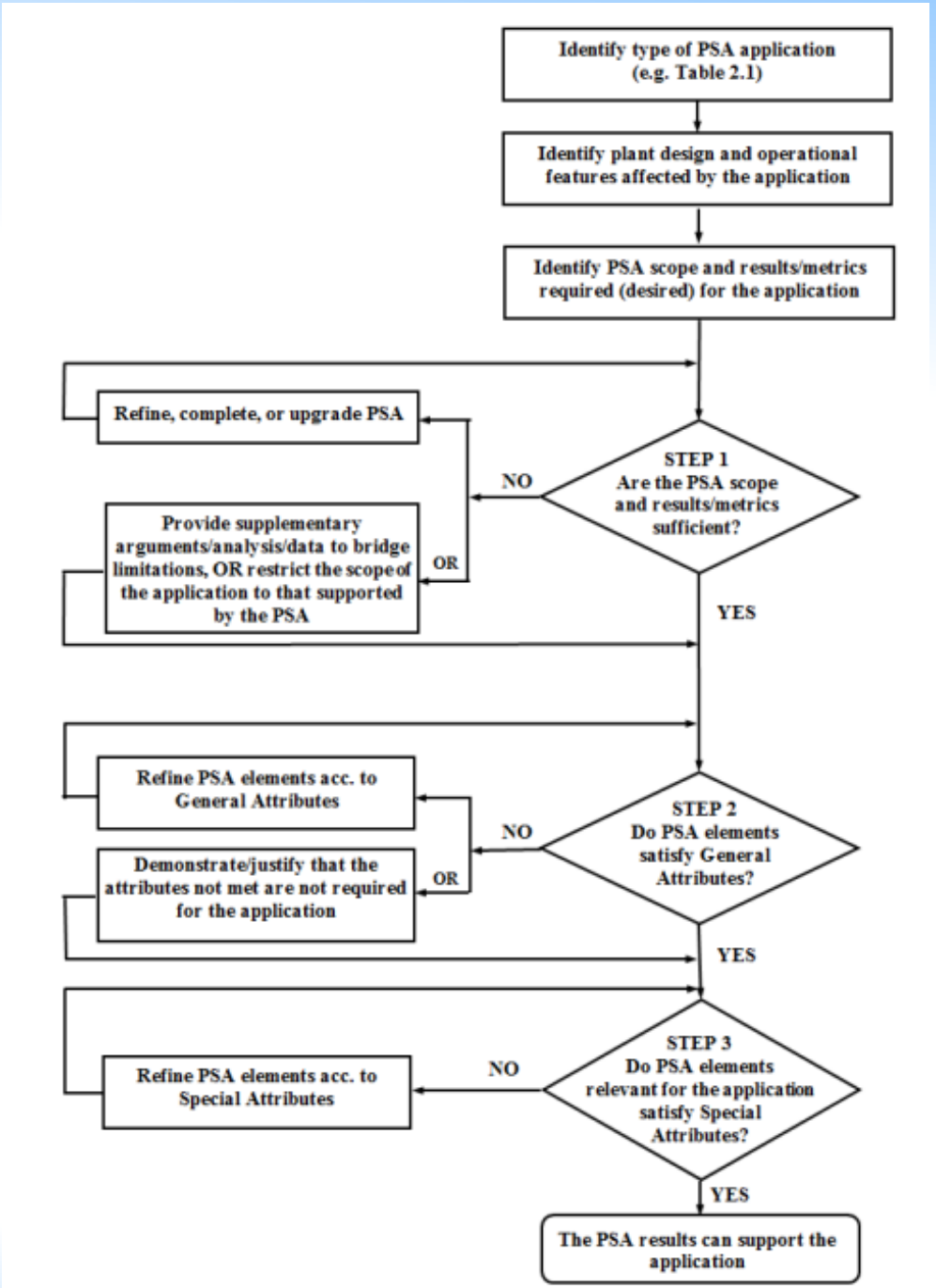
Task / GA	Characterization of Task/General Attributes *Identifier and Description of Special Attributes (in Italics)*		Rationale/Comments/Examples for: General Attributes and *Special Attributes (in Italics)*
AS-B	For each initiating event group for internal events, internal hazards, and external hazards for each POS the key safety functions that are necessary to reach a success end state are identified. Success and non-success end states are clearly defined.		COMMENT: If the scope of the PSA does not include certain hazards or LPSD POS, then these do not have to be considered.
AS-B01	The success and non-success states are defined in a manner that provides the possibility to justify the achievement (non-achievement) of the success end state for each accident sequence with the use of available tools (e.g. thermal hydraulic analysis, tests and experiments, etc.). All end states are identified as success or non-success; no end state is undetermined.		RATIONALE: Undefined end states prevent the capability for a useful interpretation of the results.
	AS-B01-S1	*For accident sequences resulting from initiating events affecting multiple reactor units, the end states must account for the success and non-success end state status of all affected units.*	*COMMENT: An initiating event that impacts a combination of N reactors on the site may result in any possible combination of reactor end states ranging from all N reactors with successful end states to all N reactors with unsuccessful end states.*
AS-B02	For each initiating event group the key safety functions are identified. Systems and procedurally directed operator actions required to perform safety functions are identified for each IE group with account for availability of specific equipment and conditions for operator actions (e.g. information available for operator, acceptability for manually controlled equipment, time window, etc.). For each safety function, system models are developed with account for success criteria defined for specific IE group and AS.		
AS-B03	A justification for the achievement of stable success end state conditions is provided for each AS with account of all uncertainties associated with the applicable tools.		RATIONALE: Ignoring the uncertainties associated with the available tools used to justify achievement of the success end state may lead to loss of significant insight of the PSA.

Quality of Level 1 PSA: Attributes

Mapping the special attributes of PSA elements to PSA applications (those attributes should be assured before using the PSA model for particular application)

PSA Application Group/ PSA Application	PSA Elements								
	IE	AS	SC	SY	HR	DA	DF	MQ	Other
3.1.3 Risk informed support for plant ageing management programme	IE-H02-S1	-	-	**SY-B19-S1** **SY-B22-S1**	-	**DA-E01-S1**	DF-F01-S1 DF-G01-S1	-	-
3.1.4 Risk informed on-line maintenance	-	-	-	-	-	-	-	MQ-A01-S1 MQ-C02-S1	-
3.1.5 Plant outage management	-	-	SC-A03-S1	-	HR-G02-S1 HR-G04-S1 HR-K02-S1 HR-K05-S1	-	-	-	OS-A03-S1 OS-C01-S2
3.2 Accident mitigation and emergency planning									
3.2.1 Development and improvement of the emergency operating procedures	-	**AS-B03-S1** **AS-C03-S1** **AS-C04-S1** **AS-C16-S1** **AS-C05-S1** **AS-C06-S1** **AS-C08-S1**	-	-	**HR-G02-S1** **HR-G04-S1**	-	DF-F01-S1 DF-G01-S1	-	-
3.2.2 Support for NPP accident management (severe accident prevention, severe accident mitigation)	IE-B01-S1	-	-	-	**HR-G02-S1**	DA-D06-S1	DF-F01-S1 DF-G01-S1	-	OS-A01-S1 HE-D04-S1
3.2.3 Support for NPP emergency planning	IE-B01-S1	AS-C05-S1	-	-	-	-	-	-	-

General procedure for determination of technical quality of PSA for applications



Quality: PSA review

- It is a widely accepted practice for the organization conducting a PSA to commission an independent peer review of the PSA from an outside body, sometimes from a different State, to provide a degree of assurance that the scope, modelling and data are adequate
- The experts involved in the review of the PSA should not be engaged in any activities relating to performance of the PSA under consideration and should represent an organization that is independent of the developer of the PSA

PSA applications: summary

- **Enhancement of safety decision making by complementing the traditional deterministic approach with a systematic probabilistic approach that is consistent and predictable**
- **Efficient use of regulatory resources and reduction in unnecessary burden on licensees**
- **Continued focus on aspects that contribute to risks of NPP operation**
- **Requires maintaining updated risk analyses models, tools, and understanding of risk implications of plant design features and processes incorporating operating experiences**

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