IAEA
International Atomic Energy Agency
Atoms for Peace and Development

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P3. Experience in PSA Applications

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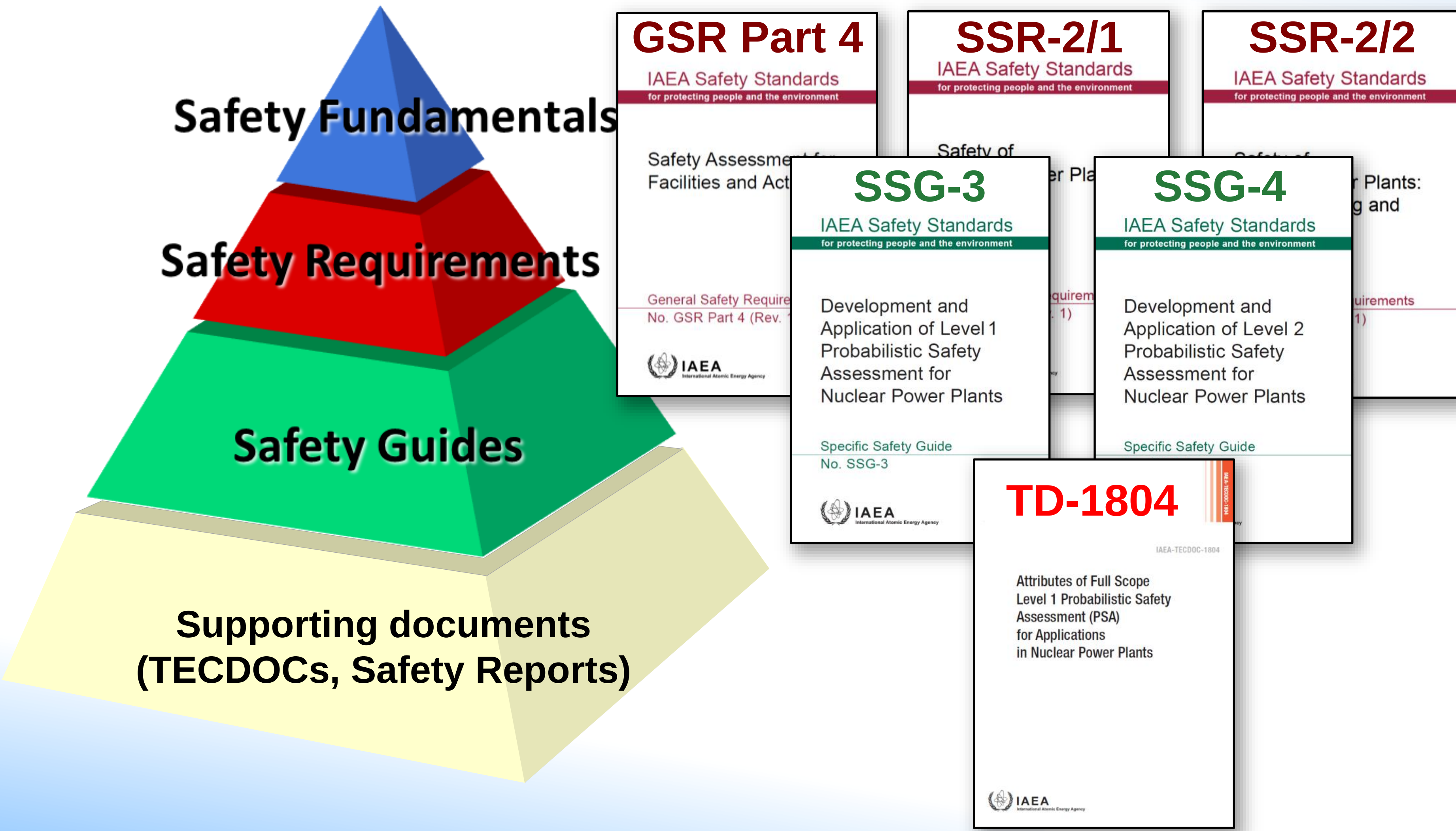
Outline

- Introduction
- Experience in PSA Applications
  - Technical specification
    - Allowed Outage Time (AOT)
    - Surveillance test
  - Maintenance Effectiveness
  - Plant modification
  - Inspection
    - inspection activities
    - inspection findings
  - EOPs

Introduction

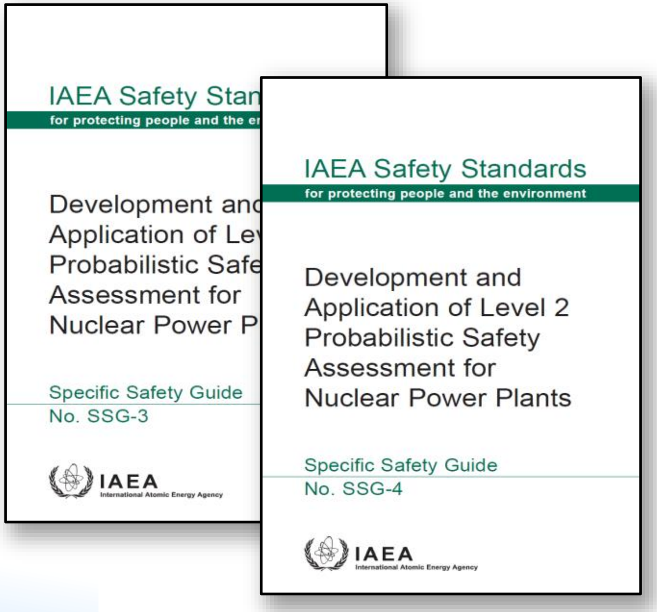
PSA applications in IAEA publications



Intoduction

PSA applications in IAEA publications: Safety Standards

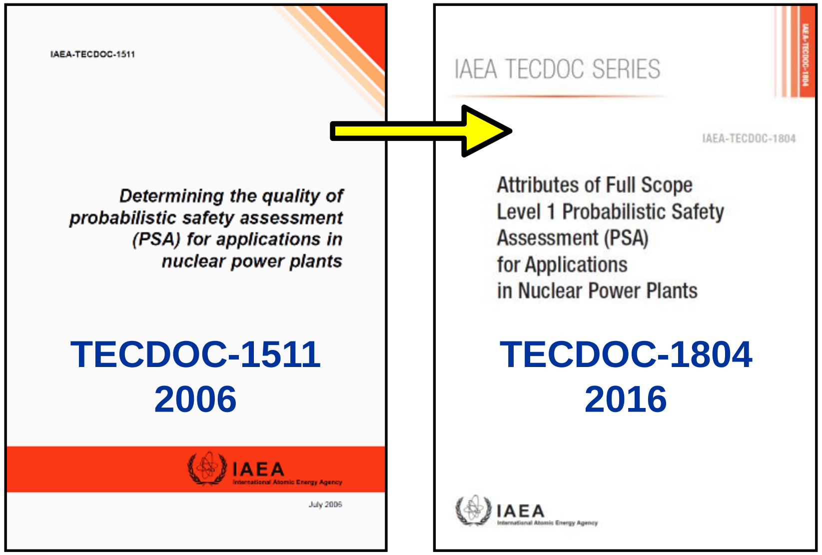
- Various PSA applications are presented in Section 10 of SSG-3 and Section 8 of SSG-4
- In PSA applications described in SSG-3 & SSG-4 insights from PSA should be used as part of Integrated Risk informed decision making (IRIDM) process considering:
  - Mandatory requirements
  - insights from deterministic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



IAEA TECDOC-1804

- 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



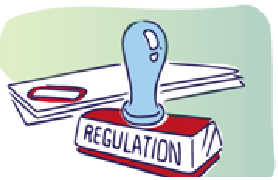
Categories of PSA applications

- **Safety assessment:** to assess the overall safety of the plant and to develop an understanding of 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)
- **Permanent changes:** to assess the safety significance of proposed permanent changes to the plant SSCs or operating procedures (help for DM)
- **Oversight activities:** to support plant performance monitoring (both regulatory and industry)
- **Evaluation of safety issues:** risk significance

Types of PSA applications

Types of PSA applications (1/3)

- **Regulatory PSA applications**
  - **Those which are directly supporting regulatory functions**
  - **Analyses and evaluations performed within the regulatory organization**



  - Support for the regulatory decision making
  - Models and tools, including methods to be available within the organization

Types of PSA applications

- **Utility PSA application**
  - **Those applications which are of specific interest to utilities**
  - **Applications focused on streamlining or easing operations, cost optimization**
  - Analyses are done by the utility (or consulting support)
  - Regulatory involvement may or not be required

- Methods and tools are often similar for both types of applications

Types of PSA applications (3/3)

Regulatory Applications

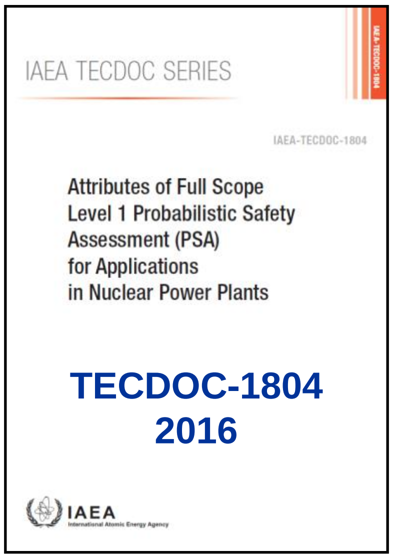
- Risk informed rules and requirements
- Training of regulatory staff
- Assessment of inspection findings
- Prioritisation of regulatory research
- Others

Utility Applications

- Technical Specification (TS) optimisation
- Development of EOPs
- Training for Operators
- Plant changes and back-fitting
- Risk informed ISI & IST
- Graded QA
- Maintenance optimization
- Surveillance program planning
- Risk monitors
- Others

Typically PSA model of the utility is applied. However some regulators develop and maintain their own PSA models

PSA applications for technical specification changes



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)

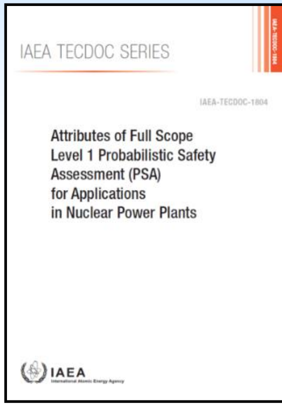
Evaluation of changes to AOTs

PSA applications for technical specification changes

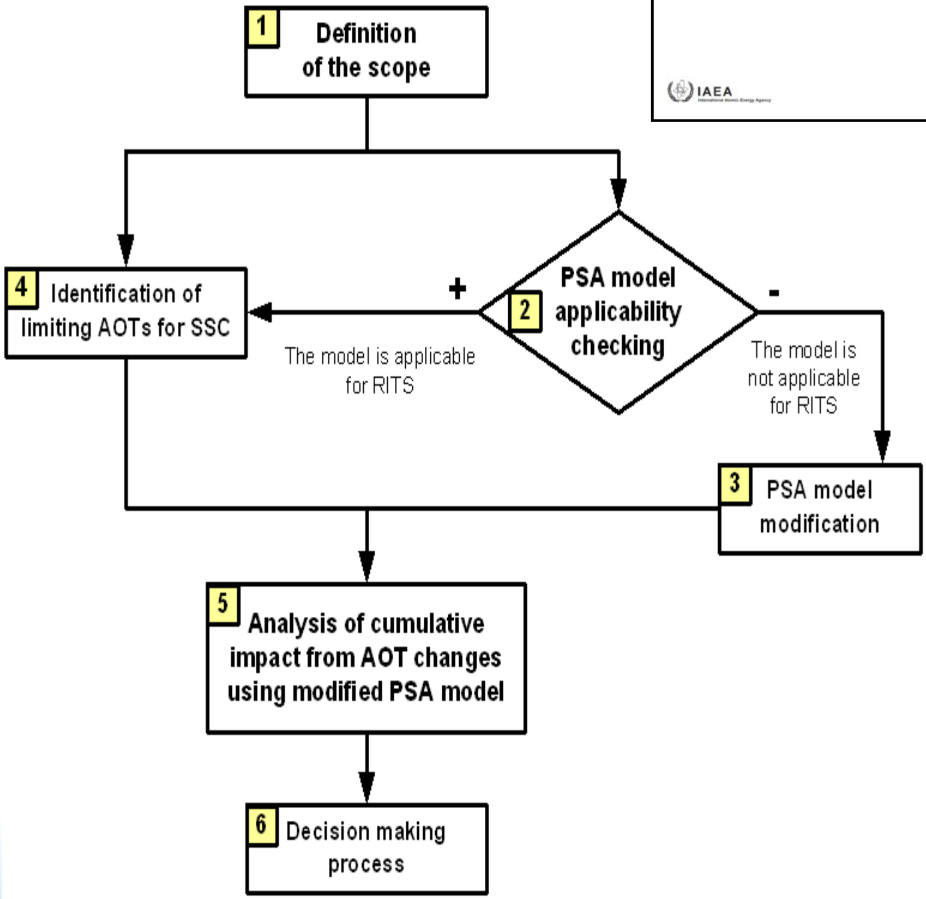
- Limiting conditions for operations (LCOs) define equipment operability requirements and allowed outage times (AOTs).
- The AOT for a particular system or component specifies the time period during power operation within which any repair or maintenance should be completed. If the AOT is exceeded the plant operating mode must change.
- PSA techniques can be used to modify or verify allowed outage times (AOT) based on a quantitative analysis of specific contributors to overall plant risk.
- The benefits from these risk based analyses can be:
  - Consistent basis for AOTs that account for the installed level of redundancy, operating configuration, equipment reliability, and risk importance of each system.
  - Justification for planned preventive maintenance schedules during power operation and during shutdown conditions.
  - Improved communication between plant operators and regulatory authorities and etc.

Evaluation of changes to AOTs

PSA applications for technical specification changes



- Defining the scope of investigation
- Defining applicability of existing PSA model for RITS improvement
- PSA model modification if necessary
- Identification of limiting AOT value for SSC
- Analysis of cumulative impact from AOT changes
- Decision making process.



Evaluation of changes to AOTs

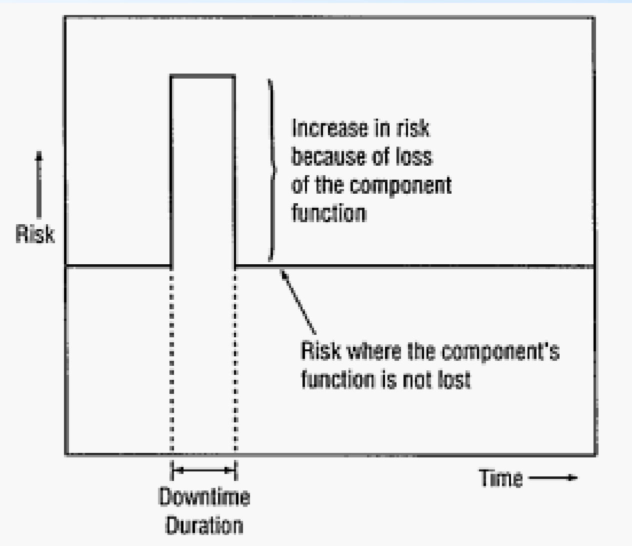
PSA applications for technical specification changes

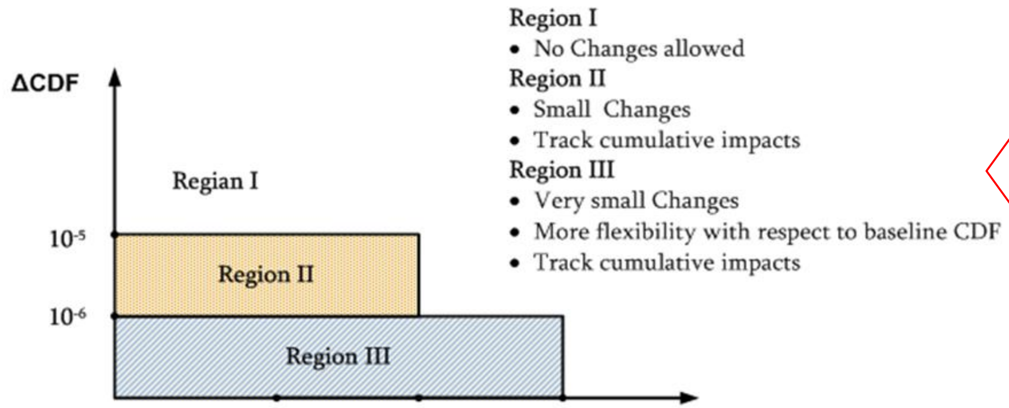
Incremental conditional core damage probability (ICCDP) is used as a limiting AOT criteria for single component. ICCDP is calculated based on following formula:

$$ICCDP = (Q_{P=1} - Q_0) \times AOT$$

Where $Q_{P=1}$ - conditional CDF that equipment out of service,

Q_0 - baseline CDF with nominal expected equipment unavailabilities.





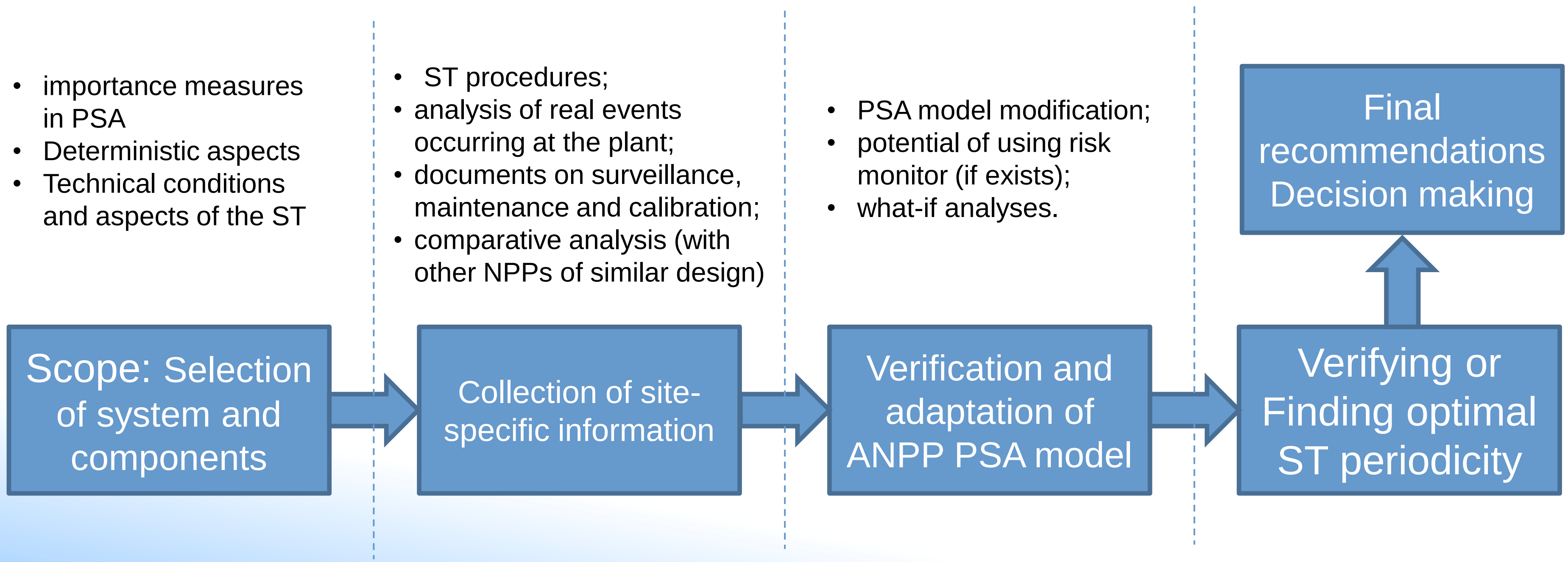
Decision making process is mainly implemented based on engineering judgment and risk increase criteria

Regulatory Guide 1.174, An approach for using PRA in RIDM on plant-specific changes to the licensing basis, U.S. NRC, November 2002

Surveillance test intervals

PSA applications for technical specification changes

- Surveillance testing is a periodic testing to verify that structures, systems and components of NPP continue functioning or are in the state of readiness to perform their functions. This is the main activity to ensure operability of NPP systems and components.
- The surveillance program of ANPP is defined based on the expert judgment and includes periodicity and duration of the surveillance tests



Surveillance test intervals

PSA applications for technical specification changes

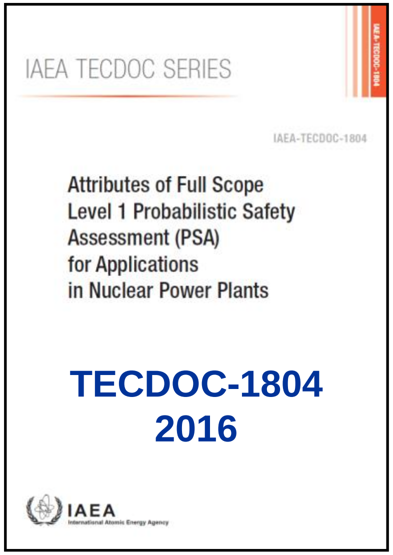
The objective of implementing analysis for selected systems is to estimate the impact of possible changes of the intervals between the regular surveillance tests. For this reason, two cases were considered:

- Case 1: twice more surveillance tests per year;
- Case 2: twice fewer surveillance tests per year.

Considered case	CDF Mean	ΔCDF	% CDF from original CDF	Increase/ Decrease
CDF Original surveillance program	3.686E-05	-	-	-
ECCS				
Case 1: Twice more surveillance tests per year	3.619E-05	6.70E-07	1.82%	**Decrease**
Case 2: Twice fewer surveillance tests per year	3.806E-05	1.20E-06	3.26%	**Increase**
Normal make-up system				
Case 1: Twice more surveillance tests per year	6.70E-07	1.00E-08	0.03%	**Decrease**
Case 2: Twice fewer surveillance tests per year	1.82%	1.00E-08	0.03%	**Increase**
Spray system				
Case 1: Twice more surveillance tests per year	3.574E-05	1.12E-06	3.04 %	**Decrease**
Case 2: Twice fewer surveillance tests per year	3.974E-05	2.88E-06	8.06 %	**Increase**
ECCS, normal make-up system and spray system				
Case 1: Twice more surveillance tests per year	3.506E-05	1.80E-06	4.88 %	**Decrease**
Case 2: Twice fewer surveillance tests per year	4.095E-05	4.09E-06	11.10%	**Increase**

Details will be presented in **P10.** Experience in use PSA for inspections, tests, and maintenance optimization

PSA applications for NPP maintenance

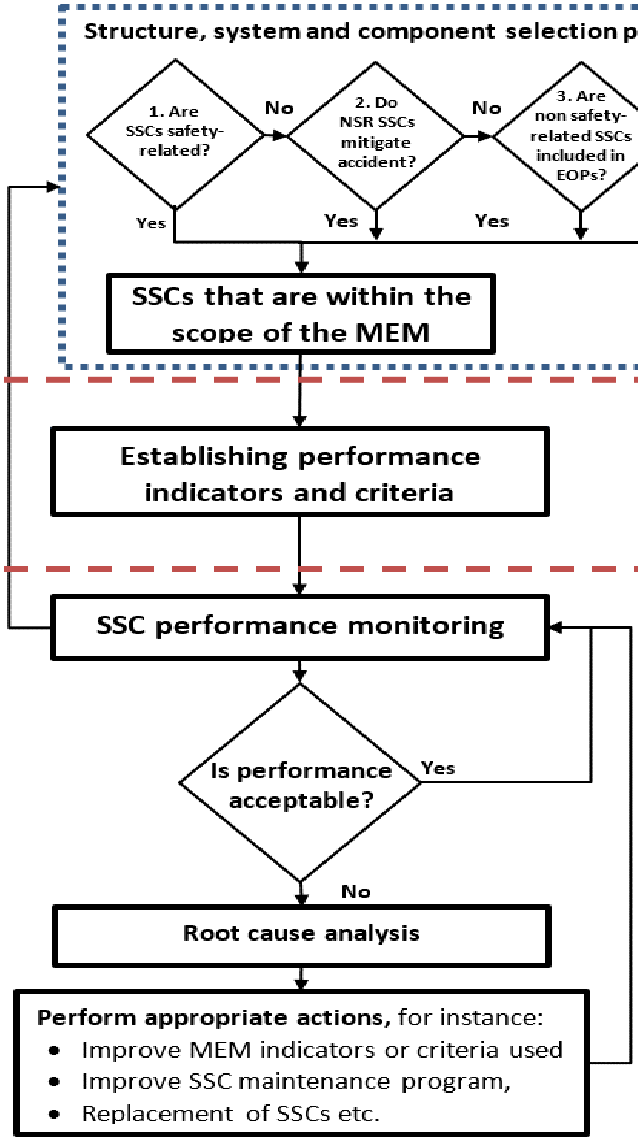


3.1. NPP maintenance	3.1.1. Maintenance programme optimization 3.1.2. Risk informed house keeping 3.1.3. Risk informed support for plant ageing management programme 3.1.4. Risk informed on-line maintenance 3.1.5. Plant outage management

PSA applications for NPP maintenance

- Maintenance activities play a significant role in safe operation of the nuclear power plant. The function of the plant maintenance program is to preserve and restore the inherent safety, reliability and availability of plant structures, systems and components for reliable and safe operation.
- Continuous monitoring of maintenance program effectiveness ensures that safety related and certain non-safety related SSCs are capable to perform their intended functions.

PSA applications for plant modifications



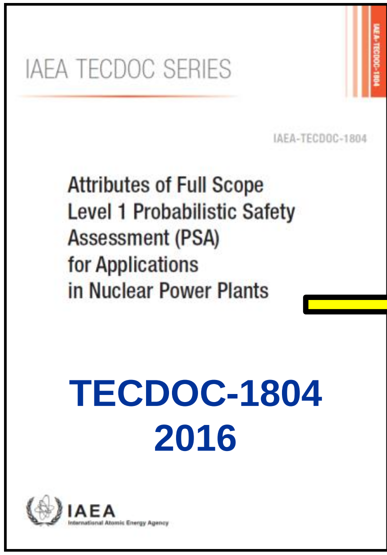
Selection of SSCs for maintenance effectiveness monitoring (MEM).

Establishing performance indicators and criteria for selected SSCs

Evaluation of SSCs performance against selected indicators monitoring process.

Details will be presented in **P10.** Experience in use PSA for inspections, tests, and maintenance optimization

PSA applications for plant modifications



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

PSA applications for plant modifications

- Identification of weaknesses and effective areas for improvement in plants design and operational features
- Justification of proposed changes - Providing additional information for regulators

- Change in CDF used to justify acceptable risk impacts and to determine risk significance

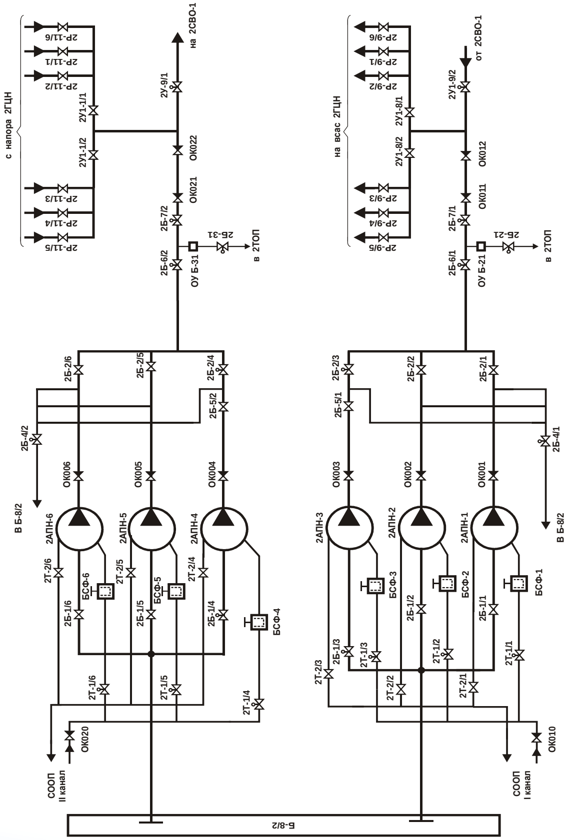
PSA applications for plant modifications

- In the regulation framework there is no particular criterion to be fulfilled in case of safety system modification.

- To assess the modification of the ECCS (SS), the reliability of the currently operated (old) ECCS (SS) was taken as a reliability criterion.

- The failure probability if the ECCS (SS) modification should be less than the failure probability of the operated (old) ECCS (SS), this will improve the reliability of the system.

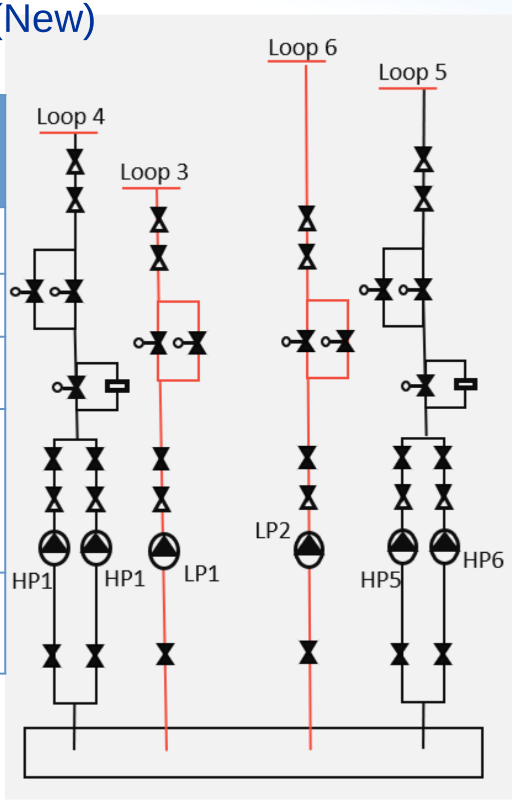
PSA applications for plant modifications



- Selection of Initiating Events
- Identification Success Criteria for Modified (New) and Operating (old) ECCS

IE	Success criteria for operated (old) ECCS	Success criteria for (new) ECCS modification
Transients	1 of 6 HP pumps	1/4 HP pumps
LOCA 9 mm	1 of 6 HP pumps	1/4 HP pumps
LOCA 9mm to 32 mm	1 of 6 HP pumps	1/4 HP pumps
LOCA 32 mm to 100 mm	1 of 6 HP pumps the overpressure protection of secondary side is required	1of 4 HP pumps or 1 of 2 LP pump are required
LOCA 100 mm to 210 mm	1 of 3 pumps from each train is required	2 of 4 HP pumps or 1 of 2 LP pump are required

- The proposed design solution was analyzed and optimizations were suggestion



PSA applications for plant modifications

The results of the reliability analysis showed that the average value of the probability of failure of the modified ECCS for all initiating events is less than the probability of failure of the operated ECCS.

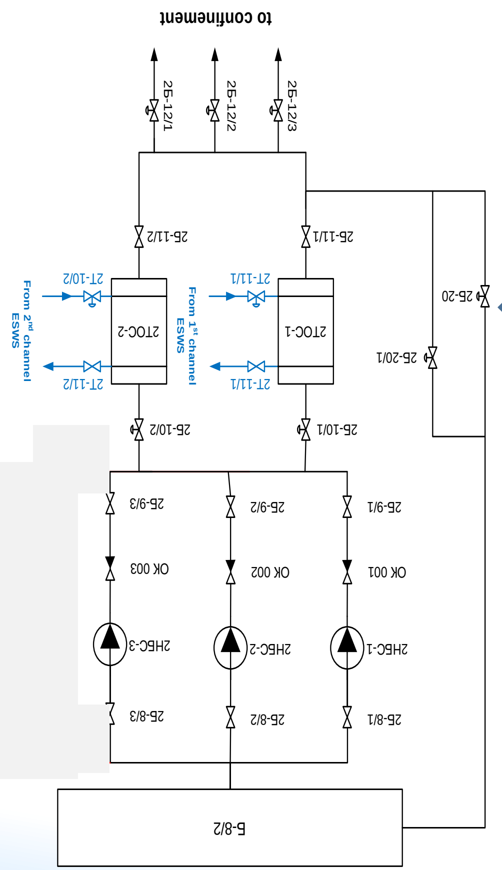
- For initiating events - "Transients", "Leak with loss of coolant with a diameter of less than 9 mm" and "Leak of coolant with a diameter of 9 to 32 mm", the introduction of the ECCS modification will increase the reliability of the system by approximately 45%.

- For the initiating event “Coolant leak with a diameter of 32 to 100 mm”, the modification of the ECCS system reduces the probability of system failure by two orders of magnitude compared to the failure of the currently operated ECCS.

- For the initiating event “Coolant leak with a diameter of 100 to 210 mm”, the ECCS modification reduces the probability of system failure by three orders of magnitude compared to the failure of the currently operated ECCS.

Based on this, it can be argued that the probability of failure of the ECCS after modification is less than the probability of failure of the currently operated ECCS, which in turn increases the reliability of the ANPP as a whole.

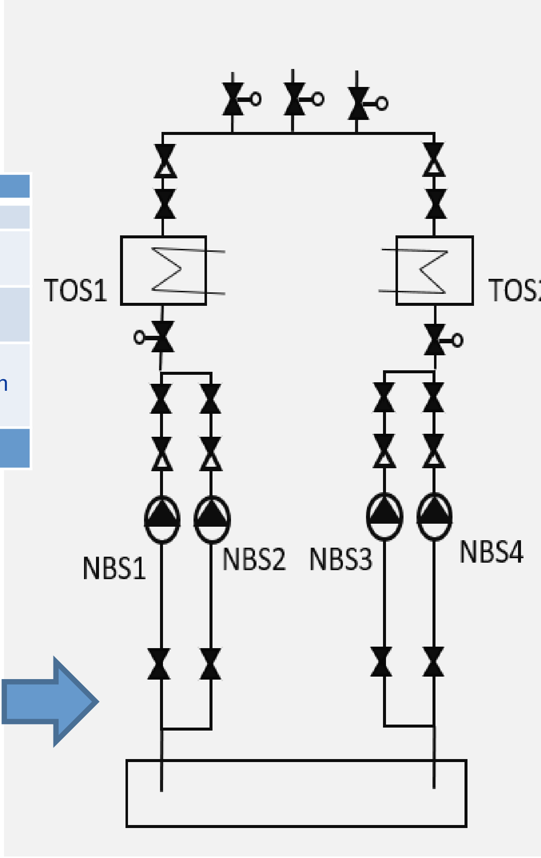
PSA applications for plant modifications



Operation modes of the old and modified SS:

Number of NBS pumps	Number of connected spray rings		
	1	2	3
1 pump	- $Q_{ф}$=401m³/h	-	-
2 pumps	- $Q_{ф}$=492m³/h	- $Q_{ф}$=780m³/h	-
3 pumps	+ if 2B-20/1 is open	+ if 2B-20/1 is open	+ $Q_{ф}$=1122m³/h
«+» – the function is fulfilled; «–» – the function is not fulfilled			

Number of NBS pumps	Number of connected spray rings		
	1	2	3
1 pump	-	-	-
2 pumps (different channels)	-	-	-
2 pumps same channels	-	+	-
3 pumps	+	+	-
4 pumps	+	+	+
+» – the function is fulfilled; «–» – the function is not fulfilled			

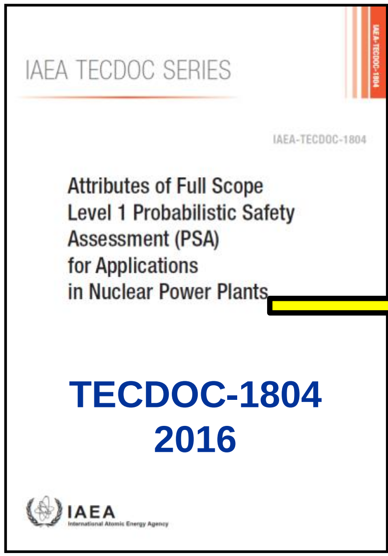


PSA applications for plant modifications

The results of the analysis showed that the probability of failure of the modified SS is two orders of magnitude lower than the reliability of the old SS.

It can be stated that the modification of the spray system **meets the defined criteria of the reliability.**

PSA applications for inspections



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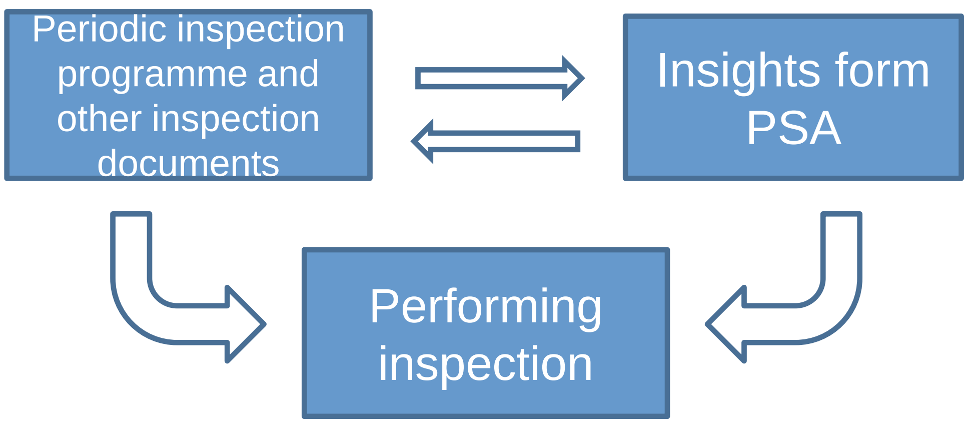
2016

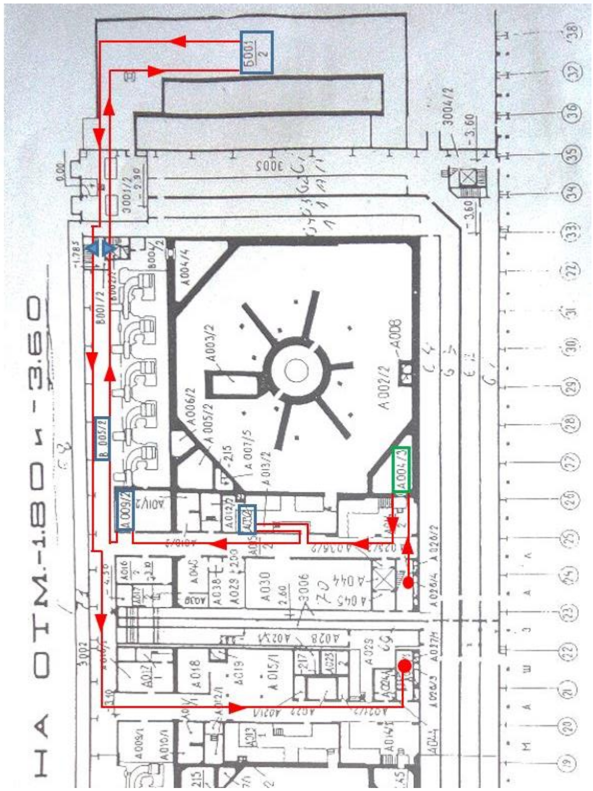
5. OVERSIGHT ACTIVITIES	5.1. Performance monitoring	5.1.1. Planning and prioritization of inspection activities (regulatory and industry)
		5.1.2. Long term risk based performance indicators
		5.1.3. Short term risk based performance indicators
	5.2. Performance assessment	5.2.1. Assessment of inspection findings
		5.2.2. Evaluation and rating of operational events

Planning and prioritization

PSA applications for inspections

Inspections are one of the primary functions of RB, that is performed to ensure that the safety regulations and rules the license is given by RB are adequately addresses and the required safety level is maintained.





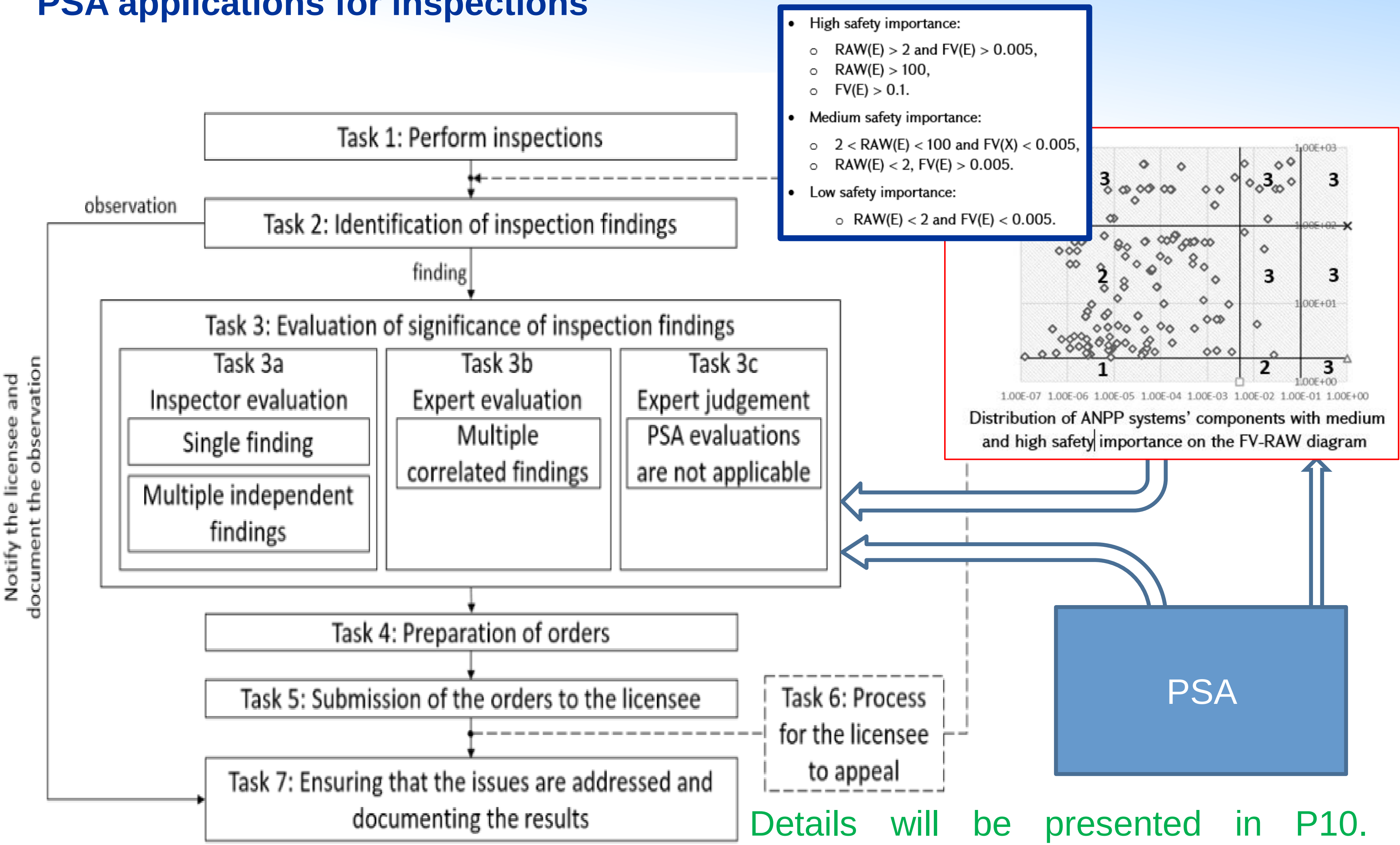
The benefits from using PSA for planning and prioritization of inspection:

- Save human resources
- Save time and financial resources
- Inspection efficiency improvement

Details will be presented in P10. Experience in use PSA for inspections, tests, and maintenance optimization

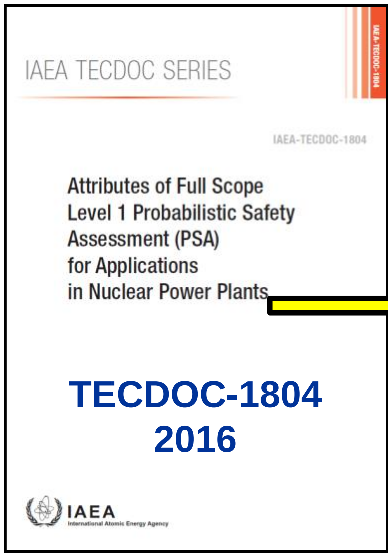
Assessment of inspection findings

PSA applications for inspections



Details will be presented in P10. Experience in use PSA for inspections, tests, and maintenance optimization

PSA applications for EOPs



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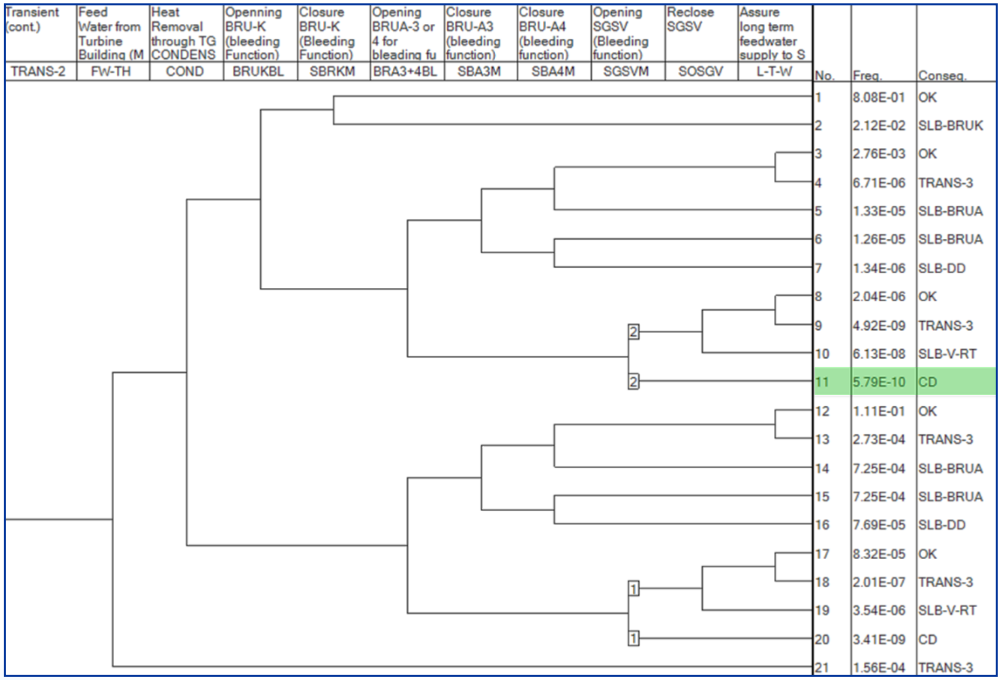
3. NPP OPERATION	3.2. Accident mitigation and emergency planning	3.2.1. Development and improvement of the emergency operating procedures
		3.2.2. Support for NPP accident management (severe accident prevention, severe accident mitigation)
		3.2.3. Support for NPP emergency planning

PSA applications for EOPs

Safety function: heat removal to ultimate heat sink

Possible accidents progressions are reflected in event trees

- 118 initiating events were considered
- 71 initiating events were selected for further analysis
- Accident progressions connected with loss of heat sink have been selected from PSA model event trees
- 109 scenarios have been selected from PSA in regard to loss of heat sink



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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Thank you!