

Meetings for Sharing International Knowledge and Experience on Stress Tests

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IAEA

International Atomic Energy Agency

Objectives

- Background
- Use of document
- Extreme Events
- Assessment methodology
- Vulnerabilities
- Main Safety Functions
- Severe Accident Management

Background

- Fact finding mission (May 2011), Ministerial Conference (June 2011)
- Strengthen nuclear safety, emergency preparedness and radiation protection of people worldwide
- IAEA Action Plan to strengthen global nuclear safety framework: *Safety assessments in the light of the accident at TEPCO's Fukushima Daiichi Nuclear Power*



Background [2]

- Based on existing IAEA Safety Standards Series documents (Requirements and Guides), and makes use of recently updated modules to existing Safety Services

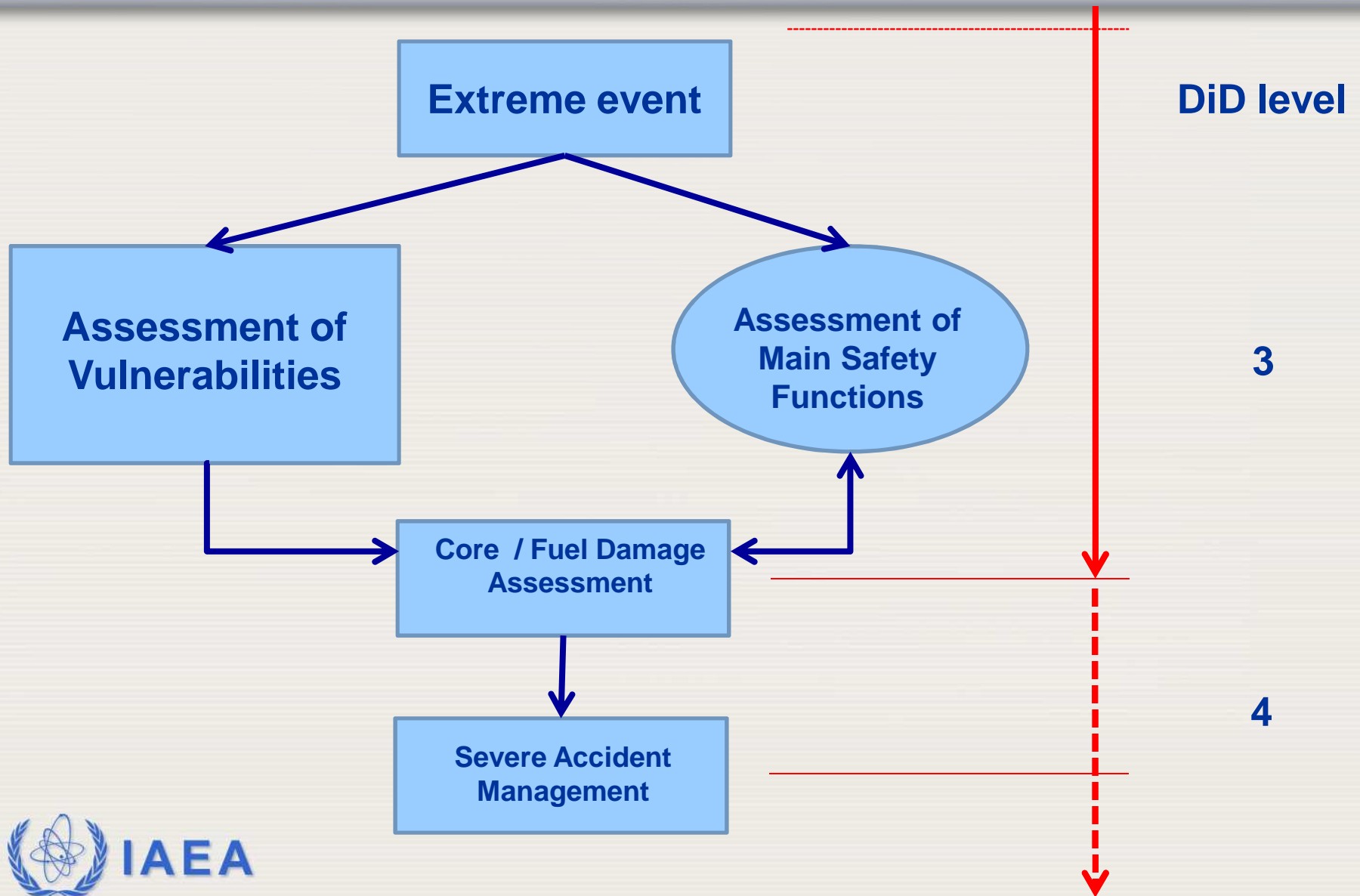
Use of document

- For Member States to conduct their own assessment of their NPPs
- Can be used also by IAEA as basis of a review of an NPP assessment.

Extreme Events

- Events or hazards of a magnitude exceeding the design basis
 - Hazards produced by external events with the annual frequency of occurrence less than those selected for design basis and higher than the screening limit (performance goal); includes low probable and high consequence events.
 - Correlated hazards or factors, e.g. earthquake/tsunami.
 - Hazards inducing other hazards in the plant, earthquakes inducing internal flood or fires.
 - Any other event external or internal to the plant provoking extensive site/plant damage, multiple common cause failures to safety equipment, and extreme plant situations

Assessment Methodology



Assessment of Vulnerabilities of NPPs against Site Specific Extreme Natural Hazards

- Selection of the methodology (deterministic and/or probabilistic)
- External Hazards Assessment (IAEA Safety Standards: NS-R-3, NS-G-3.1, SSG-9, NS-G-3.4, NS-G-3.5 (DS417), NS-G-3.6, DS-405.
- Selection of the Review Level Hazards (Consistent with the performance and safety goals - NS-G-2.13)
- Design Review, and Data Collection relevant for the external hazards considered - NS-G-2.13, NS-G-1.5, NS-G-1.6, NS-R-1.
- Deterministic safety margin analysis (NS-G-2.13)
- Probabilistic external events safety analysis (NS-G-2.13)

SMA and SPSA METHODOLOGIES (NS-G-2.13)

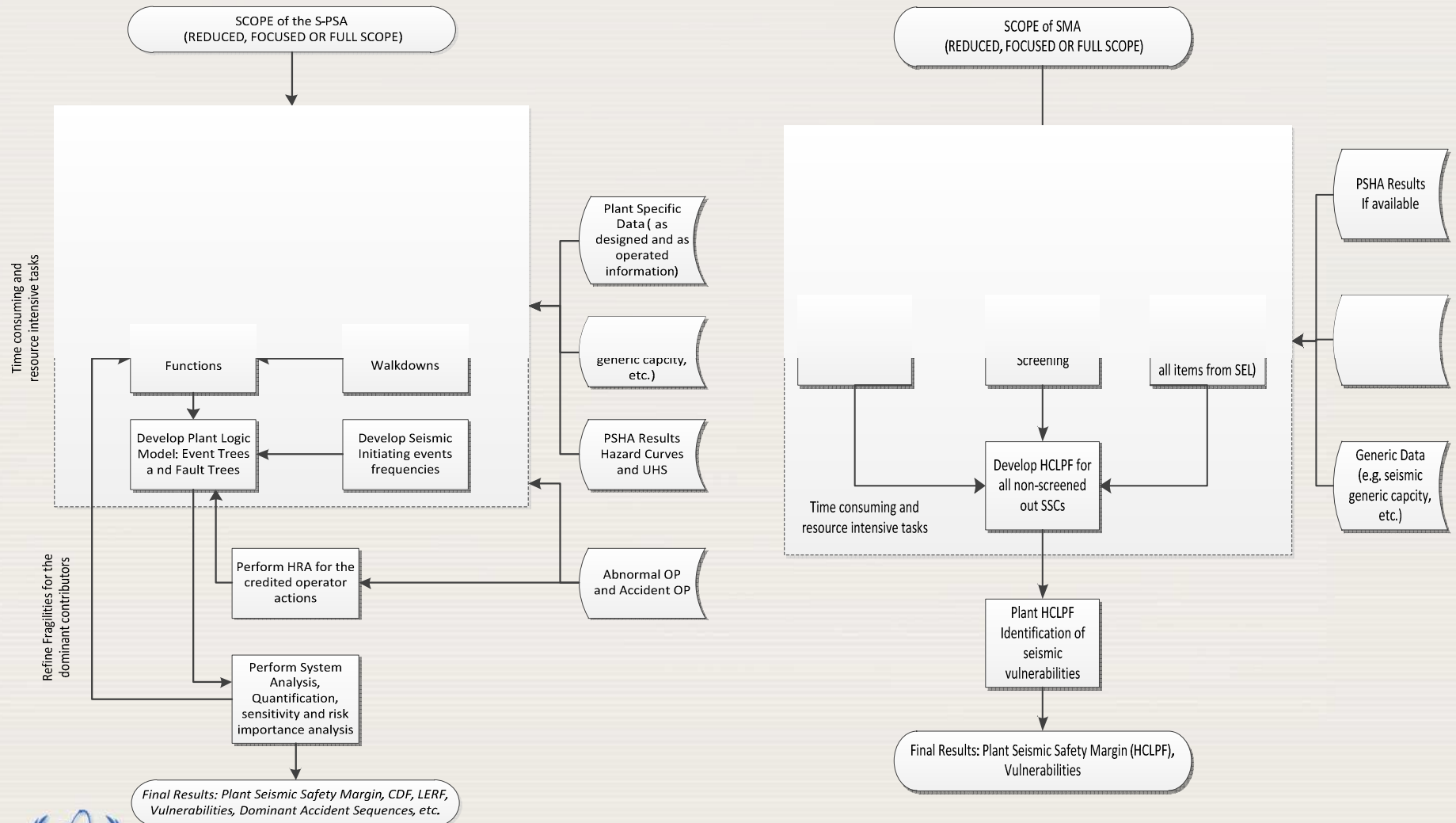
SMA STEPS:

- Selection of the assessment team
- Selection of the review level earthquake
- Plant familiarization and data collection
- Selection of success path(s) and SSEL
- Determination of the seismic response
- Plant walkdown for seismic capability
- HCLPF determination for selected SSCs
- HCLPF calculations for the NPP
- Enhancements to the programme (e.g. seismic induced fire and flood, detailed relay reviews)
- Peer review
- Documentation.
- Detailed Methodology is described in US-DOE EH 545 and/or EPRI NP 6041
- SMA Methodology will be detailed in the new SR that will replace Safety Report Series 28

S-PSA STEPS:

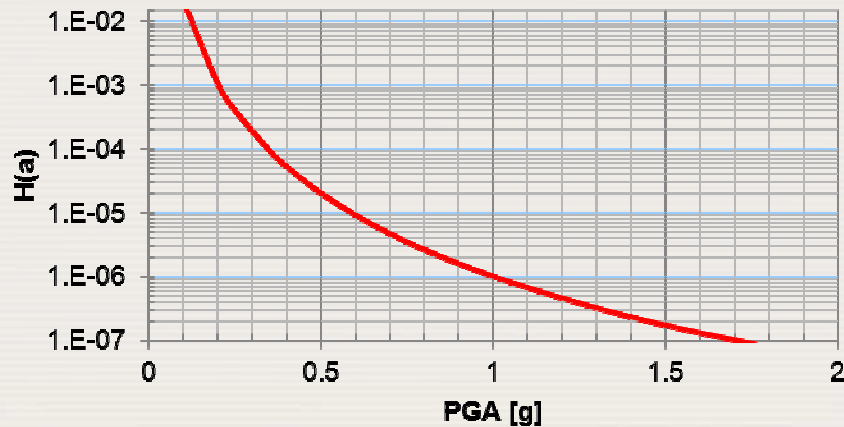
- Selection of the assessment team
- Seismic hazard assessment
- Plant familiarization and data collection
- Determination of the seismic response
- Plant Walkdowns for seismic capability
- Fragility calculations for selected SSCs
- Systems and accident sequence analysis
- Human reliability analysis for seismic events
- Risk quantification for the NPP
- Enhancements to the programme (e.g. seismic induced fire and flood, detailed relay reviews)
- Peer review
- Documentation
- Detailed methodology described in US-EPRI Implementation Guide 1002989
- SPSA Methodology will be detailed in the new SR that will replace Safety Report Series 28

Seismic Margin and Seismic-PSA

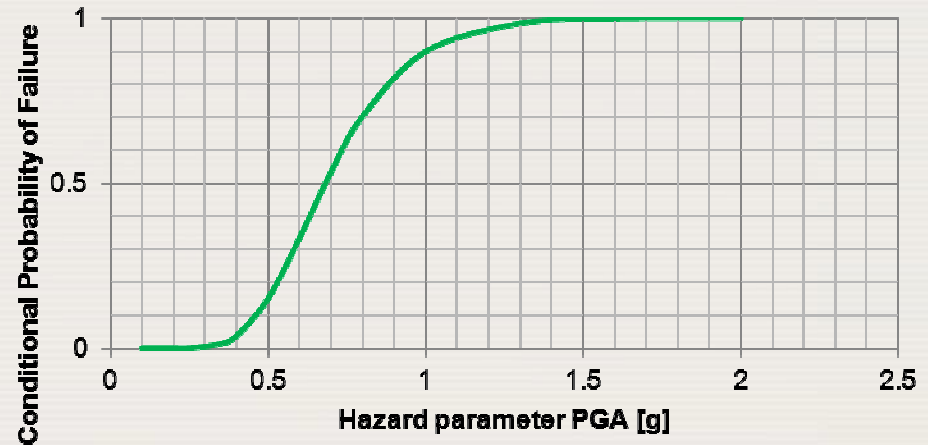


Relation Between Design Capacity, Safety Margin and Performance Goal

Seismic Hazard



Plant Fragility



$$H(a) = K_i a^{-K_h}$$

K_i = scaling parameter

$$K_h = 1/\text{LOG}_{10}(A_R)$$

A_R = Slope parameter

$$\beta = \sqrt{\beta_r^2 + \beta_u^2}$$

$$CDF = K_I A_m^{-K_h} e^{0.5(K_h \beta)^2}$$

DBE	T	SF	HCLPF	Am	CDF
0.12	100	1.00	0.12	0.24	1.14E-03
0.17	475	1.00	0.17	0.34	2.40E-04
0.20	1000	1.67	0.34	0.68	1.23E-05
0.35	10000	1.67	0.58	1.16	1.23E-06

Short / Long Term Hazard Assessment

- In the short term conservative estimates based on design base review expert judgment and conservative assumptions may be used for parameter characterizing the hazards.
- The hazard parameters should be estimated satisfying the requirements of IAEA Safety Standard. Effort should be made to follow the guidelines of IAEA Safety Standard.
- Short term hazard assessment is expected to produce conservative results as compared to long term hazard assessment.
- Long term hazard assessment should be done adopting detailed analytical approach for evaluation of hazard parameters based on the requirements and guidance of IAEA Safety Standards and validated industry practice.

Short / Long Term Safety Assessment

- In the short term the deterministic SMA can be used together with conservative assumptions aimed to reduce the list of SSCs that require HCLPF evaluation. Furthermore the HCLPF evaluation can be conducted using conservative assumptions base on design review and expert judgment.
- All these assumptions and engineering judgments should be well documented and the conservatism of the assumptions used should be demonstrated.
- Theses simplifications should lead to a conservative estimate of the plant seismic safety margin as compare to the full scope SMA results.
- On Long Term full methodology should be implemented. In high hazard areas probabilistic method is recommended (e.g. S-PSA).

Assessment of Main Safety Functions(MSFs)

- Deterministic assessment, independent of probabilities.
- Assessment of safety system architecture against IAEA SSs.
- Assessment of additional provisions by assuming progressive impact on MSFs. Analysis of recovery actions – time to core/fuel damage.
- Identification of weaknesses
- For determining impact of other event scenarios on plant
- Analysis focused on support system failures:
 - Higher potential for plant wide impact on safety systems
 - More exposed to hazards
 - Confirmed by experience
 - Loss of power supply & Heat sink, as an envelope for others

Assessment of MSFs - Details

- Scope of the Assessment:
 - Consideration of accident scenarios leading to core damage (CD) in the reactor
 - Consideration of severe accident management up to the point of a large release to provide information for later parts of the methodology;
 - accident scenarios involving other sources, e.g. spent fuel pool (SPF)
 - interactions between plant units at multi unit sites
 - Consideration of all plant operational modes. Conservative assumptions regarding the plant initial conditions . All units in the plant are affected simultaneously
- Assessment of design strengths, e.g. redundancy, diversity, physical separation and other features to cope with stepwise losses of supply sources and functionality. Measures in place or that could be taken to avoid limiting situations
- Scenarios for:
 - Loss of AC Power supply: 1) Loss of off site power, 2) Station Black out, 3) Failure of additional back up equipment
 - Loss of ultimate heat sink
 - Combined loss of heat sink and station black out

Severe Accident Management

- Assessment of robustness of 4th level of DiD. Mitigation of SA.
 - Last level in the hands of the operator. Failure leads to high consequences. Potential for cliff edge effects
 - Focused on confinement of radioactive material

- 1st step Assessment of current provisions:
 - Organizational aspects, technical and human resources
 - Accident management program. SAMGs, and operational aspects
 - Plant design features

- 2nd step – Identification / Review of extreme event issues
 - Identification of weaknesses
 - Proposals for improvements

- 3rd. Reassessment of the severe accident management programme

Severe Accident Management – Details

1st step Assessment of current provisions: Description/analysis of:

- Description Organizational aspects, technical and human resources:
 - Organization and means for managing severe accidents and nuclear emergencies, roles of the organizations, human resources, emergency plans, emergency centres,
 - Equipment and installations for accidents and emergencies: protection, radiation monitoring, communication and information systems, etc.
 - Operation: training, drills, surveillance and inspection
- Accident Management Programme
 - Basis. Development of AM strategies and guidelines
 - I&C capabilities and limitations. Operational aspects
 - Transition EOPs to SAMGs. Accident Management measures
- Plant design features. Capabilities for :
 - In vessel retention of molten core, preventing recriticality.
 - Ensuring and maintaining containment isolation, preventing by-pass
 - Protecting the containment from overpressurization (cooling, venting, etc.), combustible gases, basemat penetration, and other SA phenomena.



Severe Accident Management – Details

2nd step. Identification / Analysis of extreme event issues

- Impact on general conditions at the plant site: access to plant areas, infrastructures, communications, conditions hampering internal work and external support.
- Habitability/conditions in key areas: Control rooms, tech. support centre
- Damages or conditions to SSCs limiting capabilities to perform under accident conditions
- For each scenario originated by an extreme event:
 - Effect on instrumentation
 - Limiting situations that could be given, e.g. depletion of batteries or water reservoirs.
 - Time available and conditions for diagnosis and timely taking remedial actions
 - Possibilities for using portable equipment
 - Available EOPs and SAMGs and adequacy for the scenario
 - Specific conditions impacting severe accident management actions
 - Competing needs for resources (human and material) / Multi unit site aspects.

Severe Accident Management – Details

3rd Reassessment of SA management programme.

- Assessment of the SA management programme adequacy
- Recommendations for improvements in organizations, infrastructures, plant design, EOPs and SAMGs, and training.
- The scope of reevaluation, level of detail and effort is very much dependent on the starting situation and the extreme events at each plant. It needs to:
 - Be comprehensive and systematic. Integrate insight from both lines of analysis
 - Address appropriateness of EOPs/SAMG all spectrum of accidents including sequences originated by extreme events
 - Assess capabilities of EOPs/SAMG for mitigating extensive damage on the site.
 - Account for cliff edge effects

Review of MSF Assessment

- Based upon Safety Standards for Design of NPPs and Safety Assessment
- IAEA provides and has conducted Design Safety Review Services (DSRS) for more than 20 years, covering all areas of the Safety Analysis Report
- Scope of the review limited and focused on relevant areas of the analysis

Review of Severe Accident Management

- Existing SA management programme can be reviewed based upon IAEA safety standards. RAMP service. Practical conduct would delay the development of national assessments
- IAEA provides a review of the final programme after addressing extreme event issues:
 - Expanded RAMP service. Extension to Extreme Event issues being developed.
 - Based upon IAEA safety standards, good industry practices and considerations for extreme events