“Overview of Level 2 PSA”
Levels of Risk Analysis

LEVEL 1 PSA

The assessment of plant failures leading to core damage and the determination of core damage frequency (CDF).

LEVEL 2 PSA

The assessment of containment response leading, together with the results of Level 1 analysis, to the determination of release magnitudes and frequencies.

LEVEL 3 PSA

The assessment of off-site consequences leading, together with the results of Level 2 analysis, to estimates of risk to the public.
Level 2 Analysis Task

- Level 1/Level 2 Interface
  \textit{(Plant Damage State Grouping)}

- Containment Response Analysis
  \textit{(Containment Strength)}

- Containment Accident Progression
  \textit{(Containment Event Trees)}

- Source Term Analysis
PSA Framework

Initiating events (frequency) → Event tree (X probabilities with uncertainties) → Accident sequences (frequency) → Plant damage states (frequency) → Selected plant damage states → Accident progression/containment event tree and states and their frequencies → Release categories/bin and their frequencies → Conditional consequence bins → Risk integration

Sensitivity analysis → Reconsideration of very infrequent sequences with high consequences

Sum = total core damage frequency

≤ 100 events

≤ 20 states

Very large number of sequences

10-20 release categories/tons

≤ 15-20 consequence bins per consequence measure
Level 1/Level 2 Interface

Core Damage sequences identified by Level 1 are grouped with respect to probable containment responses to

Plant Damage State Groups (PDS)

Each Plant Damage State (PDS) is the entry point to a

Containment Event Tree (CET)

The PDS grouping criteria can be best displayed in sorting tree diagram (PDS Logic Diagram).
PSA Level 1/Level 2 Interface Diagram

LEVEL 1
ETs

IE1
IE2
IE X

CD/PDS

1 3
5 4
23

LEVEL 2
CETs

PDS 1
PDS 2
PDS 7
PDS X

STC

1 2
3
X

STC frequency
Source Terms

PDS DIAGRAM

1 2 3
7
23

STC DIAGRAM

1 2 3
7
X

IAEA Training Course on Safety Assessment of NPPs to Assist Decision Making
## Example of the PDS Grouping Criteria

<table>
<thead>
<tr>
<th>Name</th>
<th>PDS Diagram Heading</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Containment Bypass</td>
<td>CONBYPASS</td>
<td>NO BYPASS ISLOCA</td>
</tr>
<tr>
<td>Integrity of Primary System Pressure Boundary</td>
<td>RCSINTEG</td>
<td>INTACT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VERY SMALL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SMALL BREAK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MEDIUM BREAK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LARGE BREAK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VESSEL RUPTURE</td>
</tr>
<tr>
<td>Availability of AC Power Supply</td>
<td>ACPOWER</td>
<td>LOST BEFORE CM</td>
</tr>
<tr>
<td>Time of Power Recovery</td>
<td>ACRECOVRY</td>
<td>BEFORE CONT FAIL</td>
</tr>
<tr>
<td>Containment Sprays Available Long Term</td>
<td>CNTSPRAYS</td>
<td>YES</td>
</tr>
<tr>
<td>Long Term Injection Available</td>
<td>VESLINJEC</td>
<td>YES</td>
</tr>
<tr>
<td>Pressure in Reactor Vessel at Core Melt</td>
<td>VESLPRESS</td>
<td>VERY HIGH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LOW</td>
</tr>
</tbody>
</table>
Containment Overpressure Capacity

- A probabilistic evaluation of the containment ultimate pressure capacity using finite element modeling

- The potential failure modes examined for e.g. VVER containment are:
  
  - Membrane failures of the containment shell
  - Failure at the containment wall - basemat junction
  - Failure of the containment wall - upper ring junction
  - Failure of the dome - upper ring junction
  - Failure of the basemat

- They were evaluated for three temperatures at the inside liner: 150 °C, 215 °C and 260 °C
Severe Accident Phenomena in Containment

- Containment failure due to over-pressurization
- Primary Coolant System
- Hydrogen burn/explosions
- Primary System depressurization
- Prior to vessel breach
- Containment atmosphere
- Containment bypass
- In-vessel steam explosions: missile generation (alpha)
- Reactor pressure vessel
- Containment
- Core melt/debris, leading to vessel breach
- High pressure melt ejection/DCH
- Ex-vessel Steam Explosions
- Corium-concrete interactions
- Basemat melt-through
Possible Containment Failure Modes