MODULE 6: Level 1 – Level 2 Interface

Outline of Discussion

- Objectives of the Level 1-2 Interface
- Technical Approach
- Examples

Objectives: Level 1-2 Interface

1. **Add containment system response to probabilistic assessment of accident definitions**
   - **Level 1 models do not consider containment systems that are not required to prevent core damage**
   - **Containment response strongly depends on availability of safeguard systems**

Objectives: Level 1-2 Interface

2. **Identify the minimum number of unique accident scenarios to be addressed in Level 2 analysis**
   - **The number of accident scenarios should be 'small' to make deterministic analysis practical.**
   - **Many accident sequences considered in a Level 1 PSA would result in similar accident progression and containment response**

Technical Approach

- **Objective-1: Add containment systems**
  - ⇒**Containment safeguards tree or bridge tree**

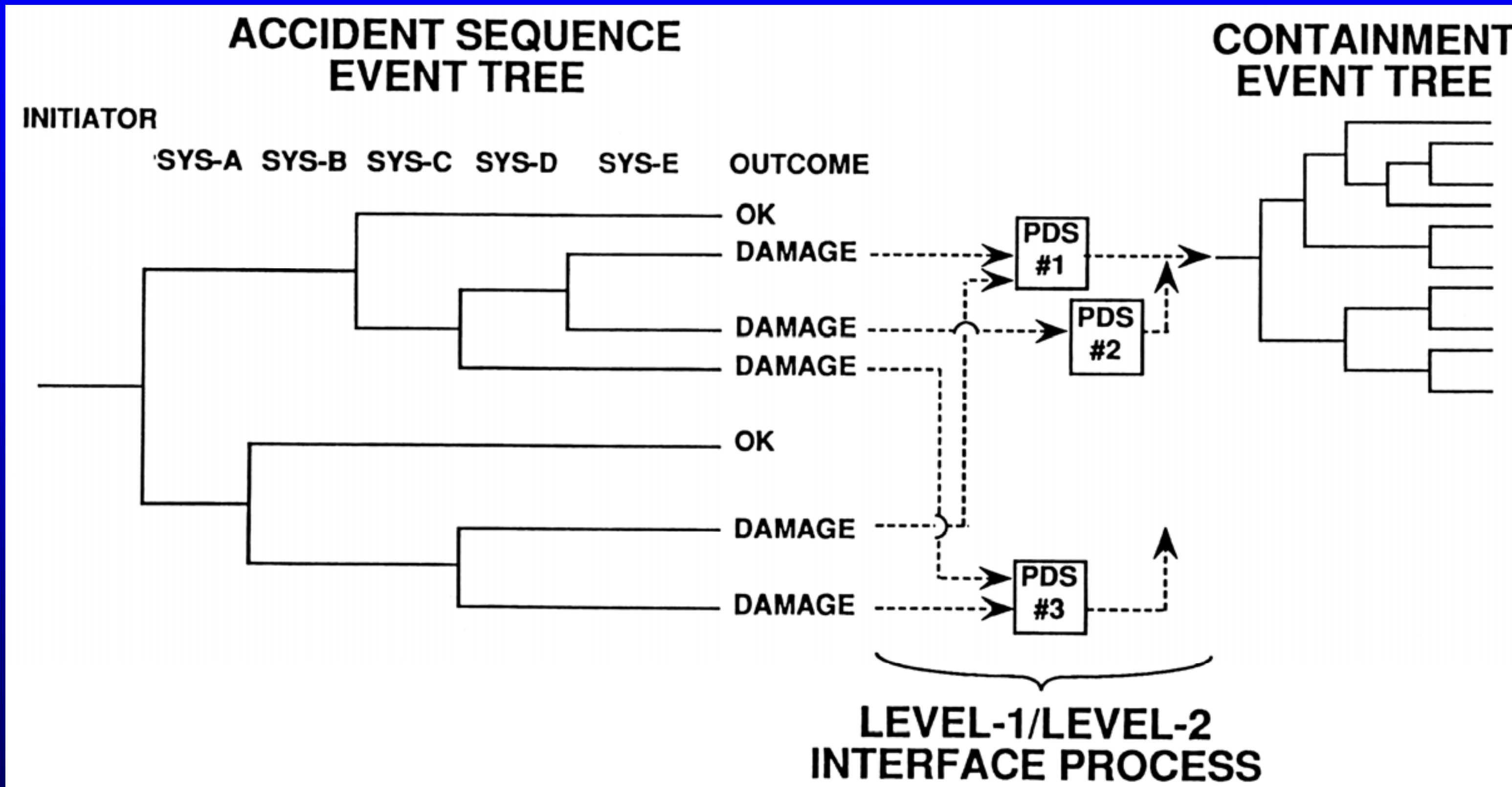
- **Objective-2: Minimize number of accident scenarios**
  - ⇒**Plant Damage State (PDS) analysis**

PDS Analysis

- Procedure: Sort core damage sequences into groups or 'bins' that represent common features of severe accident progression:
  - Accident timing
  - Release pathways for fission products to containment
  - Energy imparted to containment

→ Each PDS represents a unique set of initial and boundary conditions to the analysis of containment response

PDS Binning Process



Sorting or Binning Criteria Define Status of Barriers to F.P. Release

Barriers	Systems
Fuel clad	**Reactor power** **Core cooling systems**
Reactor vessel	**Safety/relief valves** **Reactor coolant system pressure boundary**
Containment	**Level of isolation** **Heat removal** **Water sources**
Retention capabilities	**Spray systems** **Pool/sump water**
Secondary/Auxiliary building	**Ventilation filters** **Building integrity**

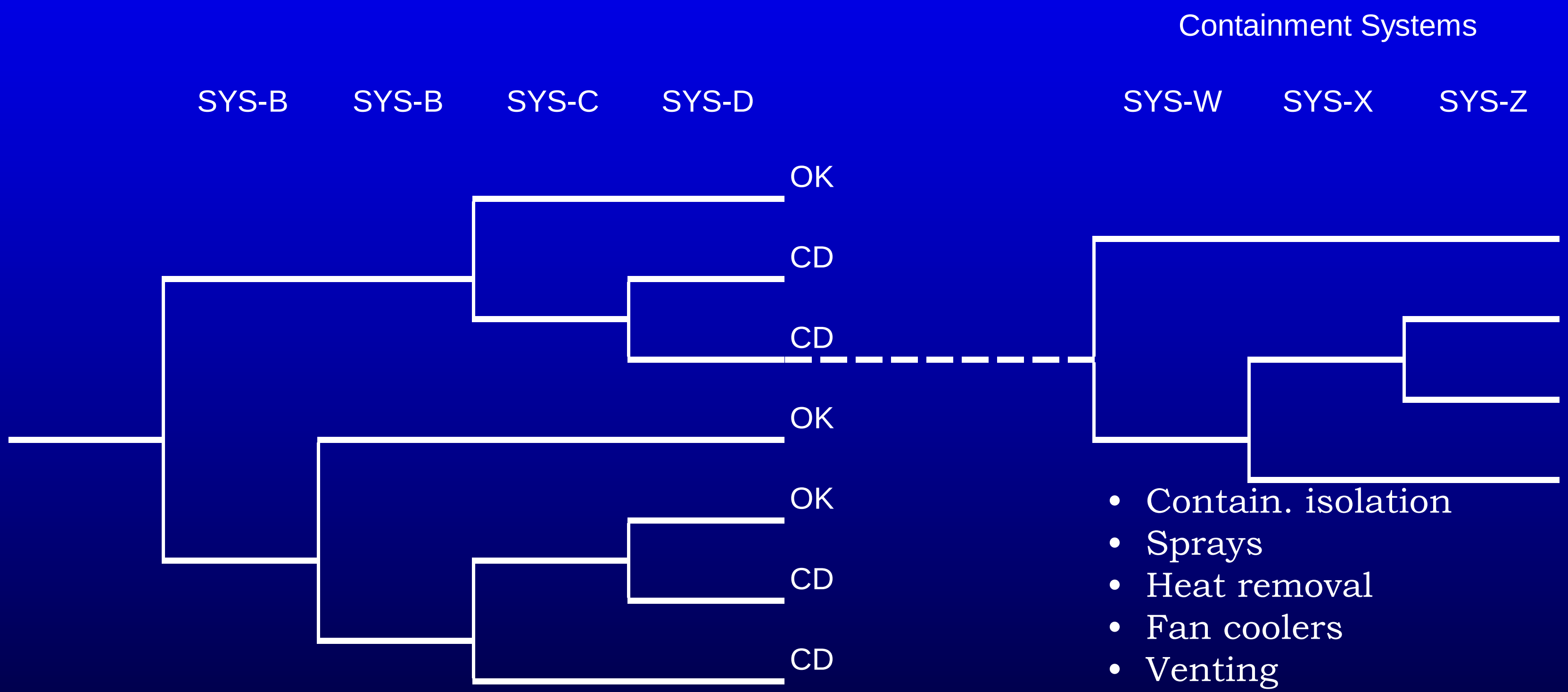
Simple Example

- Sequence 1: Transient, No coolant makeup to reactor vessel
  - Cut Set 1A: T1 * injection valves (T1 = LOSP)
  - Cut Set 1B: T2 * pumps
  - Cut Set 1C: T1 * diesel generators
- Sequence 2: Transient, Coolant injection fails in long-term
  - Cut Set 2A: T1 * heat removal * containment
  - Cut Set 2B: T2 * heat removal * (vent) * pumps cavitate
  - Cut Set 2C: T2 * pump cooling

Cut Set	Coolant Injection	Contain. Isolation	Containment Spray	PDS
1A	Fail	OK	OK	1
1B	Fail	OK	Fail	2
1C	Fail – recoverable	OK	Fail – recoverable	2’
2A	Fail	Fail	Fail	3
2B	Fail	Vent	Fail	4
2C	Fail	OK	Fail	2

Containment Safeguards Tree

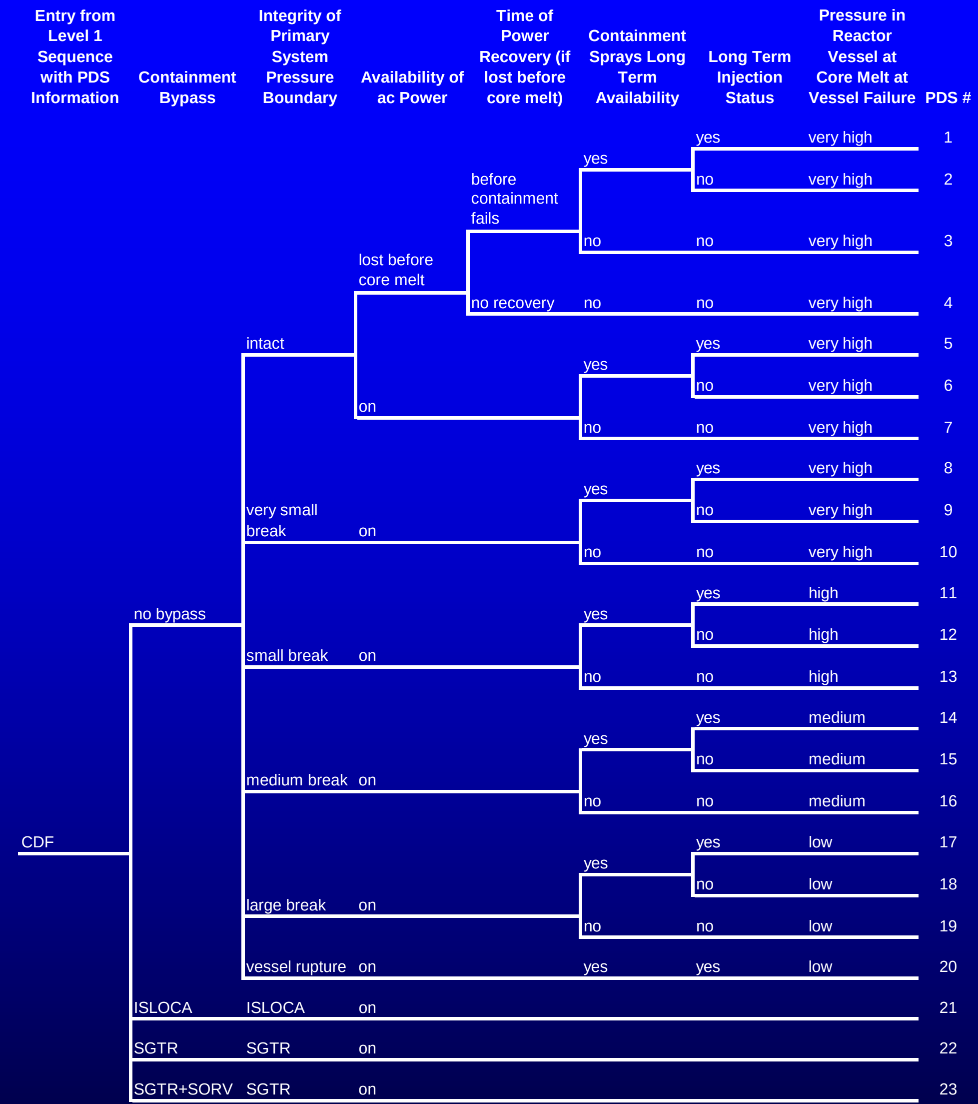
- **Extend Level 1 sequence event trees to include containment systems**



Examples from Past PSAs

- PDS results presented in several forms
  - Graphical (event tree format)
  - Tabular (matrix)
  - Character string (vector format)
- Content of various forms is the same
  - Only a preference in presentation

Graphical format



Tabular format

Conditions at the time of vessel breach		Primary Containment Intact at Time of Core Melt?																				
		Yes															No					
		Secondary Building Isolated?															Secondary Building Isolated?					
		Yes										No (C)					Yes				No (F)	
		Ventilation OK?															Ventilation OK?					
		Yes (A)					No (B)										Yes (D)		No (E)			
Vessel pressure	Water on Contain. Floor?	Water to Core Debris?					Water to Core Debris?					Water to Core Debris?					H_2O to debris?		H_2O to debris?		H_2O to debris?	
		Yes			No		Yes			No		Yes			No		Yes	No	Yes	No	Yes	No
		Containment cooled?					Containment Cooled?					Containment cooled?										
		Yes (I)	No				Yes (I)	No				Yes (I)	No									
			Vented?		Vented?			Vented?		Vented?			Vented?		Vented?							
			Yes (J)	No (K)	Yes (L)	No (M)		Yes (J)	No (K)	Yes (L)	No (M)		Yes (J)	No (K)	Yes (L)	No (M)	(K)	(M)	(K)	(M)	(K)	(M)
High	--																					
	Dry																					
Low	Wet																					

Character string format

H.P. Station Blackout:
T1-B2-X

SLOCA without heat removal:
S2-U2-W

	Attribute	State Identifier	State Description
(1)	Initiating event	A	LBLOCA: Large [1] LOCA
		S1	IBLOCA: Intermediate LOCA [2]
		S2	SBLOCA: Small [3] LOCA
		V	LOCA outside containment
		T1	TLOP or PLOP: Loss of offsite power
		T2	SORV: Stuck-open SRV/PRV
		T3	Other transients
(2)	Reactor status	--	Scram; no fission power
		C	Power above decay heat (no scram)
(3)	Electric Power status	--	Electric power available
		B1	Onsite ac power failed, dc OK
		B2	Onsite ac and dc power failed
(4)	Vessel pressure at onset of core damage	--	Vessel depressurized[5]
		X	Vessel at high pressure[6]
(5)	High pressure coolant injection status	--	HPI available as required
		U1	HPI operates until batteries exhausted
		U2	HPI not available
(6)	Low pressure coolant injection status	--	LPI available
		V	LPI not available
(7)	Containment heat removal status	--	RHR available
		W	RHR not available
(8)	Containment	--	Intact (design basis leakage only)
		Y1	Failure of containment isolation
		Y2	Containment venting successful

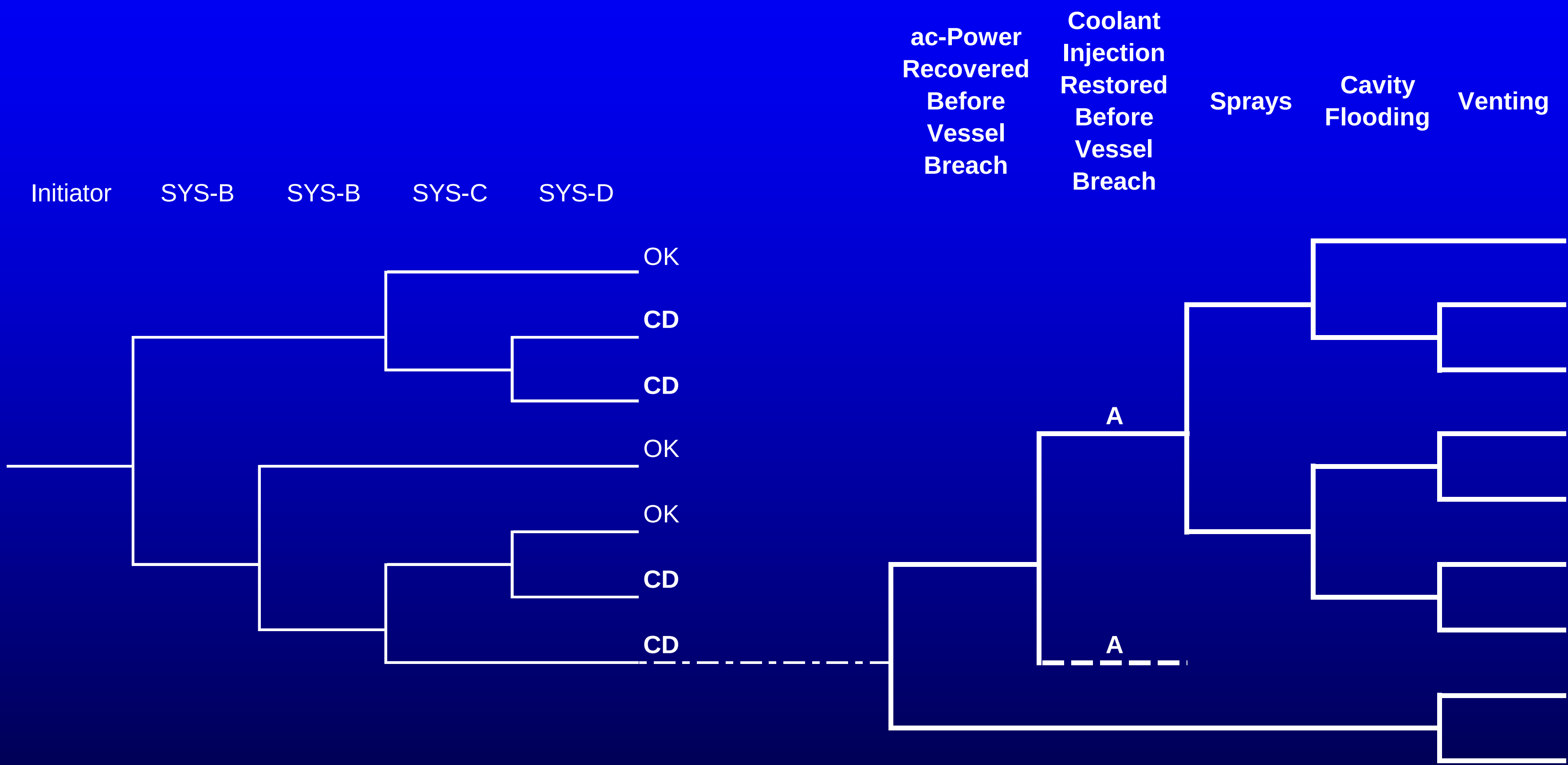
Dependencies

- Containment safeguards tree(s) must be directly coupled to Level 1 sequence events trees to properly handle dependencies
  - Shared components
  - Common support systems
  - Prior human actions

An Optional Extension
(Containment Safeguards → Bridge Tree)

- Extend period of accident recovery to vessel breach
  - Restoration of ac power after onset of core damage
  - Post-core damage operator actions (severe accident management guidelines)
    - Reactor vessel depressurization
    - Reactor cavity flooding
    - Containment venting
- Requires some knowledge of timing of in-vessel core melt progression

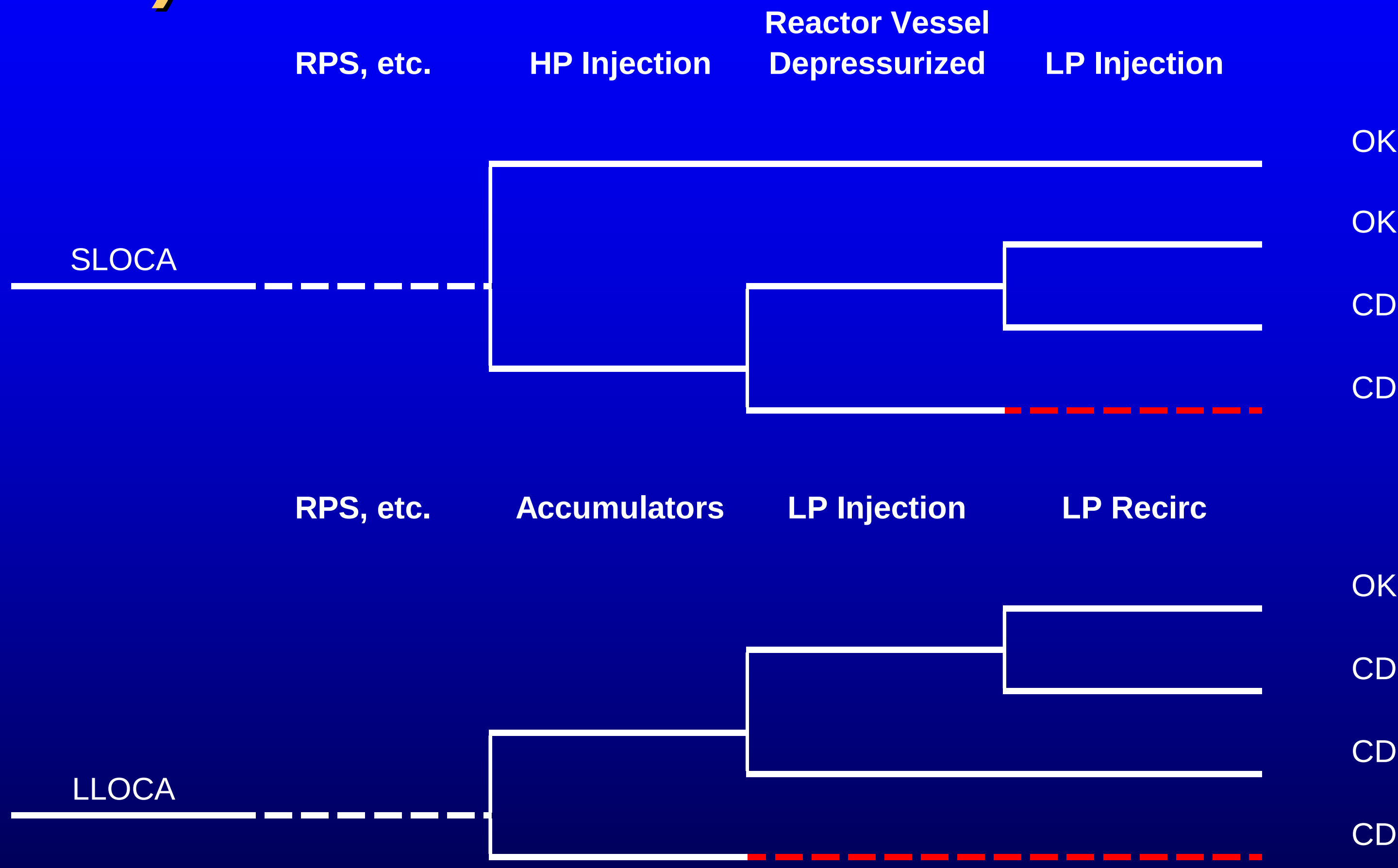
Example Bridge Tree



Final Issue: Resolution of the Status of 'Abandoned' Systems

- The status of certain systems important to the Level 2 may be 'unknown' from the Level 1
  - Sequence event trees ignore branches at locations where success criteria have already been violated
  - Success or failure not decisive for preventing core damage, but can influence subsequent severe accident progression
- Example: LOCA with failure of one part of injection success criteria

Examples of Unresolved System Status (LP-ECCS)



Summary

- Level 1 – Level 2 Interface is an analysis task
  - Couple Level 1 core damage sequence information with new information on containment system availability
  - Translate sequence cut sets to initial and boundary conditions for analysis of containment response
- Supporting deterministic analysis (code calculations) may be necessary to properly group ‘similar’ accident sequences