SH2705 Simulation Course

Event Classifications

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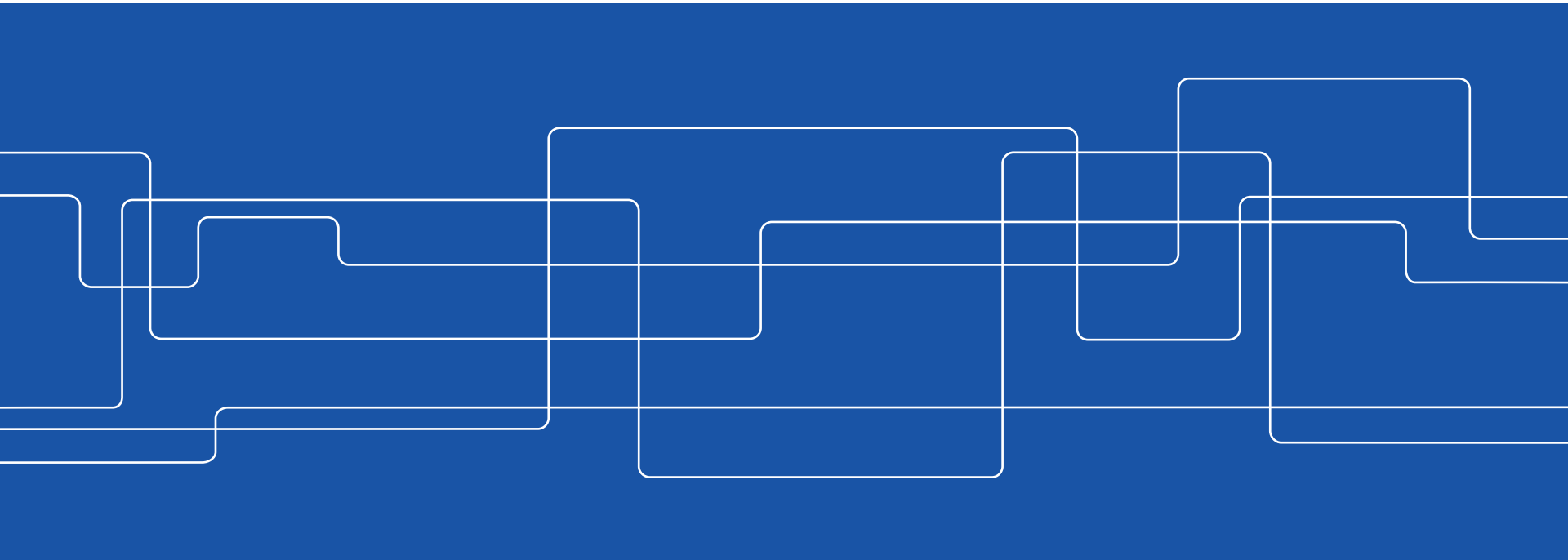
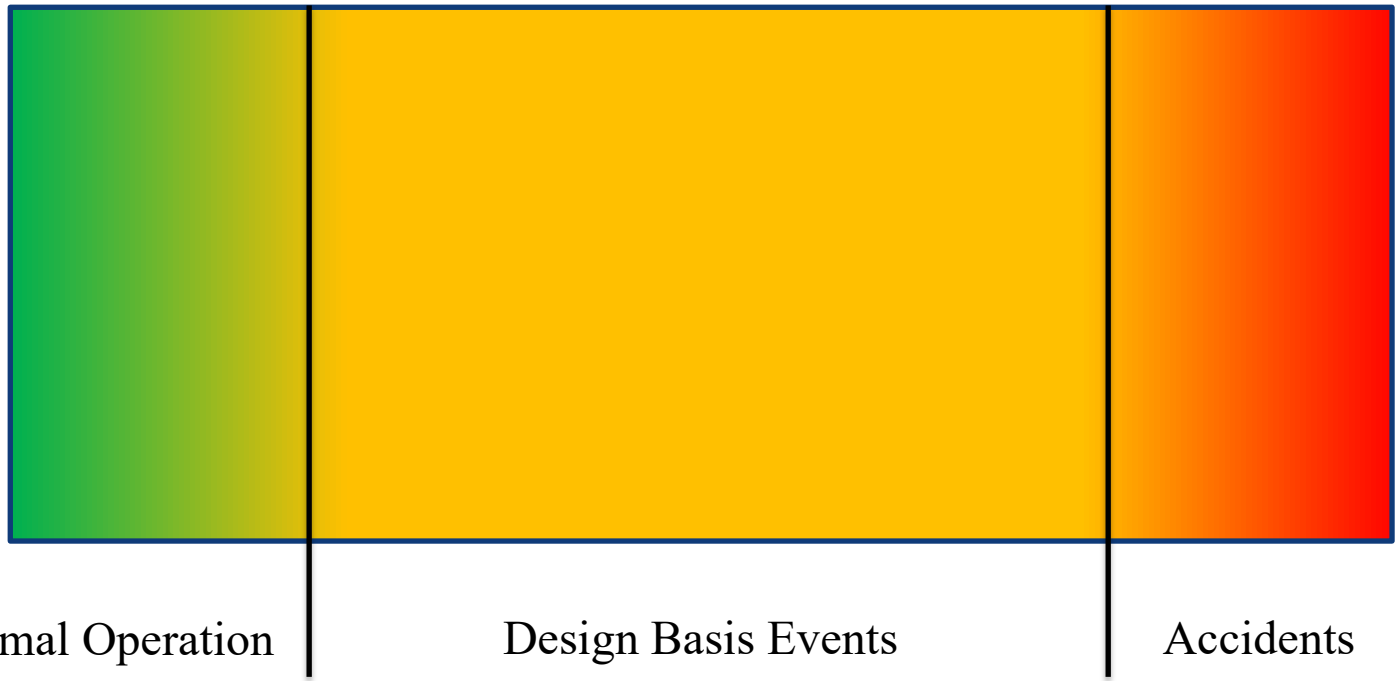



Normal Operation
Design Basis Events
Accidents

Events Classification: Categorization

IAEA Typical Plant Conditions categorization			
Plant Condition Category	**Expected Occurrence**	**Examples of events for the plant condition**	**Safety design objectives**
Normal Operation a) Steady state b) Other states	a) Most of the time b) Once or more times per year	a) Power operation b) Startup and shutdown, refueling, maintenance, testing	Plant variables not to exceed approved operating limits. No loss of structural integrity
Anticipated operational Occurrences	Several occurrences during plant lifetime	Loss of feedwater flow, turbine trip, loss of off-site power	Orderly plant shutdown. No safety restrictions on subsequent plant operation.
Accident conditions **DBE**	Infrequent, perhaps never during the plant lifetime	Loss of primary coolant beyond normal make-up capability, major fuel handling accident, sudden insertion of a large positive reactivity into the reactor	Maintenance of structural integrity, functional capability and operability of systems used to mitigate accident conditions. Controlled plant shutdown and hold-down.

DESIGN BASIS EVENTS

- The range of conditions and events taken explicitly into account in the design of a plant, so that the plant can withstand them w/o exceeding authorised limits, by the planned operation or safety systems.

- A DBE is described by:
  - Specified failure (or set of failures)
  - Initial conditions
  - All the control and safety systems operated as designed

DESIGN BASIS EVENTS cont.

- The DBEs are classified in CATEGORIES, roughly depending on their expected occurrence frequency and potential consequences.
- Categories included are Anticipated Operational Occurrences (AOOs), and Design Basis Accidents (DBAs).
- For each category, the Deterministic safety analysis (DSA) checks that the design meets the ACCEPTANCE CRITERIA, that normally reflect the criteria used by designers or operators and are consistent with the requirements of the regulatory body.

ANTICIPATED OPERATIONAL OCCURRENCES

- AOOs: operational processes deviating from normal operation that have the potential to challenge the safety of the reactor. According to design provisions, AOOs do not cause any significant damage to items important to safety, nor lead to accident conditions.

- AOOs are expected to occur at least once during the operating lifetime of the plant (frequency of occurrence higher than 0.01 per reactor and year).

Design Basis Accidents

- **Design basis**: The range of conditions and events taken explicitly into account in the design of a facility, according to established criteria, such that the facility can withstand them without exceeding authorized limits by the planned operation of safety systems. Used as a noun, with the definition above. Also often used as an adjective, applied to specific categories of conditions or events to mean 'included in the design basis'; as, for example, in design bases accident, design bases external events, design basis earthquake, etc. (IAEA glossary)
- DBAs are not expected to occur during the lifetime of the plant (frequency 10^{-2} to 10^{-5} per reactor and year, some events such as LBLOCA are even less frequent).
- Evolutionary reactors also include severe accident in design.

Design Basis Accidents

- Strictly speaking DBA applies to accidents (infrequent & limiting faults) that design of the Engineered Safety Systems and Emergency Procedures covers:
  - Containment isolation.
  - Containment cooling.
  - Containment spray.
  - Containment air treatment.
  - Containment control of combustible gases
  - Emergency core cooling system (ECCS)
  - Residual heat removal (RHR)
  - Auxiliary feedwater system.
  - Control room habitability

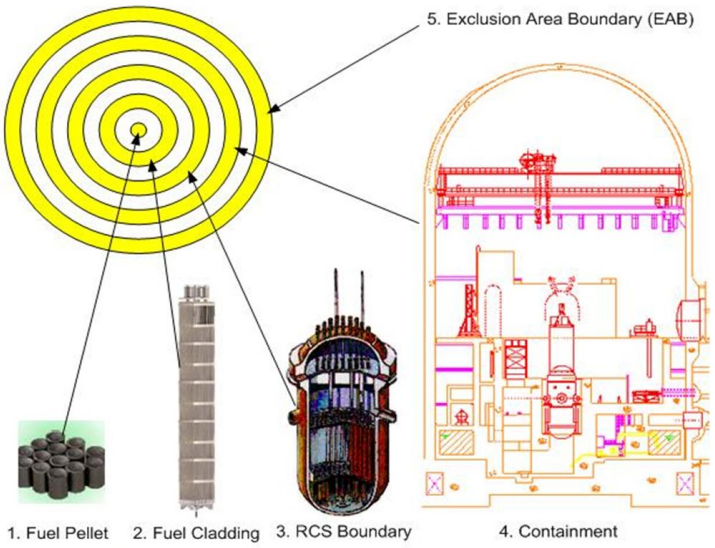
Design Basis Accidents

- DBA serve as grounds for required safety functions:
  - Fuel coolability and limited fuel damage
  - Containment integrity.
  - Limited containment leakage.
  - Scrubbing of fission products within the containment to drains.
- Standard accidents:
  - LBLOCA, SBLOCA, control rod drive mechanism (CRDM) break, etc.
- Usually limiting accident is doubled ended Large break LOCA cold leg, loss of off-site power, minimum safeguards & DB earthquake.

Design Basis Accidents

To be considered in Defense in Depth Strategy (NS-G-1.2)

Level	Objective	Essential Means
Level 1	Prevention of abnormal operation and of failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and emergency procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response



Physical barriers between reactor core and the environment

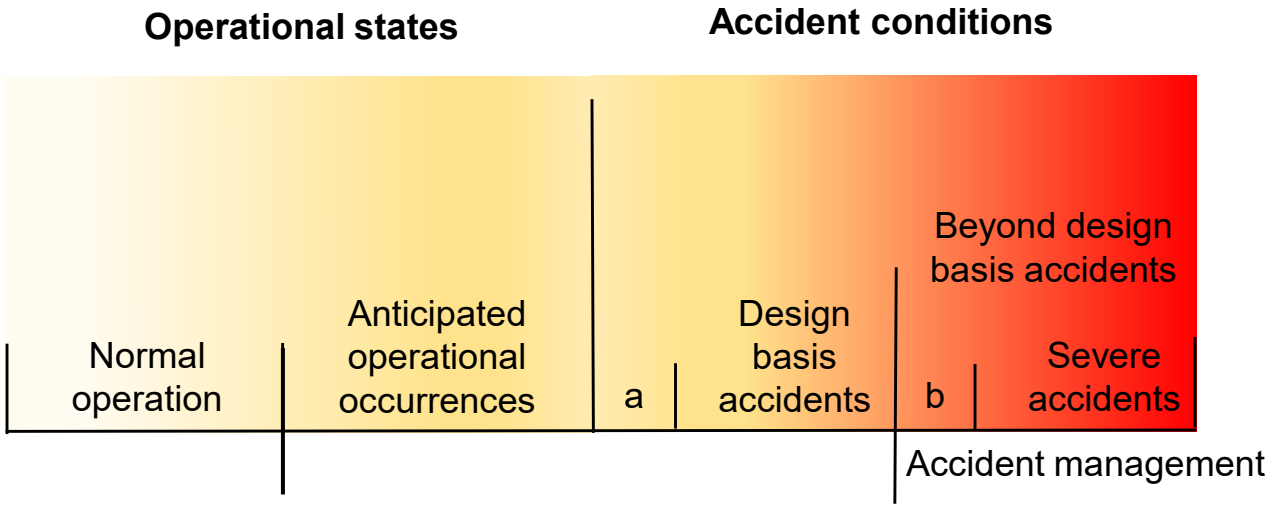
Beyond Design Bases Accidents & Severe Accidents.

- BDBA assume initial and or boundary conditions (hypothesis) not postulated in DBA because of their low credibility. i.e.:
  - Initial cond.: Catastrophic SG tube failure.
  - Vessel head break.
  - Bound. cond.: degraded ECCS, loss of RHR...
- Severe accident is a category of BDBA leading to core melt due to multiple failures.
- Progression is analyzed by different Probabilistic levels:
  - Core damage PSA-1
  - CD + RCS fail PSA-2
  - CD+ RCS fail + Containment fail PSA-3

Beyond Design Bases Accidents & Severe Accidents.

- Prevention:
  - Severe accident management guides (SAMG)
  - International cooperation: “Convention on assistance in the case of a nuclear accident or radiological emergency”
  - Additional equipment.
- Mitigation:
  - Emergency response:
    - On-site
    - Off-site
    - International: “Convention on early notification of a Nuclear Accident”

Plant States



a = Accident conditions which are not explicitly considered design basis accidents but are included by them.

b = Beyond design basis accidents without significant core degradation.

Events Classification: Categorization

Sweden		France / Germany		USA ANSI/ANS 51.1	
H1 (Normal operation)	$F > 10$	PCC1 : operational transient	$F > 10$	PC-1	$F > 10$
H2 (Anticipated events)	$10 > F > 10^{-1}$	PCC2 : anticipated operational occurrences	$10 > F > 10^{-2}$	PC-2	$F > 10^{-1}$
H3 (Infrequent events)	$10^{-1} > F > 10^{-3}$	PCC3 : infrequent accidents	$10^{-2} > F > 10^{-4}$	PC-3	$10^{-1} > F > 10^{-2}$
H4 (Improbable events)	$10^{-3} > F > 10^{-5}$	PCC4 : limiting accidents	$10^{-4} > F$	PC-4	$10^{-2} > F > 10^{-4}$
H5 (Very improbable events)	$10^{-5} > F$			PC-5	$10^{-4} > F > 10^{-6}$
Extremely improbable events	$10^{-7} > F$				

Postulated Initiating Events (PIEs)

- PIEs are starting point for the Safety analysis. They are identified events that led to AOOs or accident conditions, including equipment failure, human errors and external events (natural or human-induced).

- The set of PIEs includes events of very low frequency or consequences, at least at the beginning of the process. Some of them can be eliminated subsequently.

- PIEs classified in terms of frequency of occurrence.

Example of PIE's Categorization: Normal Operation, PC-1

- Startup
- Shutdown (hot and cold)
- Refuelling
- Hot standby
- Power operation
- During any of the above:
  - Accommodation of normal range of internal effects (i.e., pressure, temperature, humidity, radiation),
  - Fuel cladding defects within plant technical specification limits,
  - Operation with specific items of equipment out of service or under testing within plant technical specification limits,
  - Plant conditions providing industrial security, see American National Standard Security for Nuclear power Plants, ANSI/ANS-3.3-1982
  - Operation with steam generator tube leakage within plant technical specification limits, or
  - Accommodation of maintenance, testing and inspection requirements (e.g., ASME Boiler and Pressure Vessel Code, Section XI

Example of PIE's Categorization: Anticipated events, PC-2

- Inadvertent chemical shim dilution
- Loss of feedwater flow
- Partial loss of feedwater heating
- Reactor trip
- Inadvertent emergency core cooling system actuation
- Inadvertent reactor coolant system depressurization by normal or auxiliary pressurizer spray cooldown
- Single operator error
- Single failure of an active component or control component (nuclear safety-related or not)
- Single failure in the electrical system (nuclear safety-related or not)
- Loss of instrument or service air compressor
- Generator trip
- Turbine trip
- Steam generator tube leakage in excess of plant technical specifications but less than the equivalent of a full-tube rupture.

Example of PIE's Categorization: Anticipated events, PC-2 cont.

- Inadvertent control assembly group withdrawal
- Partial loss or interruption of reactor coolant flow, excluding reactor coolant pump locked rotor
- Partial loss of safety-related equipment cooling or area cooling (e.g., loss of one cooling train)
- Control rod drop
- Reactor coolant system depressurization by inadvertent operation of an active component (e.g., a safety valve or relief valve)
- Minor reactor coolant system or connecting system leakage that would not prevent orderly reactor shutdown and cooldown using only makeup provided by normal makeup system
- Fire limited to one fire area
- Minor power conversion system leakage that would not prevent orderly reactor shutdown and cooldown using only makeup provided by normal makeup systems
- Reactor – turbine load mismatch, including loss of load, excess load and turbine trip, (causes could b secondary system equipment failure, such as mail steam isolation valve, loss of feedwater flow, or partial loss of feedwater heating)

Example of PIE's Categorization: Infrequent events, PC-3

- Reactor coolant system leakage that would not prevent a controlled reactor shutdown and cooldown
- Power conversion system leakage that would not prevent a controlled reactor shutdown and cooling
- Loss of offsite ac power, including consideration of voltage and frequency disturbances
- Operation with a fuel assembly in any misoriented or misplaced position
- Inadvertent primary containment spray actuation
- Minor fuel handling accident
- Complete loss or interruption of forced reactor coolant flow excluding reactor coolant pump locked rotor
- Full rupture of one steam generator tube

Example of PIE's Categorization: Improbable events, PC-4

- Small LOCA
- Drop of a spent fuel assembly involving only the dropped assembly
- Leakage from spent fuel pool in excess of normal makeup capability
- Single reactor coolant pump locked rotor
- Blowdown of reactor coolant through multiple safety or relief valves
- Rupture of any non-seismic Category I vessel containing radioactive materials
- Control rod withdrawal error such that plant technical specification limits could be exceed
- Any design basis moderate energy line crack or high energy line break outside primary containment except in the main steamline upstream of the turbine stop valve or the main feed line downstream of the feedwater control valve.

Example of PIE's Categorization: Very improbable events, PC-5

- Major LOCA, up to and including the largest justified pipe rupture in the reactor coolant pressure boundary
- Single control rod ejection
- Major power conversion system pipe rapture, up to and including the largest justified pipe rupture
- Drop of a spent fuel assembly onto other spent fuel assemblies
- Station Black Out (SBO)
- Anticipated Transient Without Scram (ATWS)

Simulation Part

Exercises

1. Pressure transient (with scram (multiple delays) /without scram);
2. Steam line break transient;
3. Feed water line break transient;
4. Feed water pump trip transient;
5. Feed water enthalpy decrease (temperature) transient;
6. Reactor power decrease transient;
7. Reactor scram transient

Project work

- **Chose one of the exercises to study the event further, make it more severe and describe how you did it and why**

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H3 (Infrequent events)	$10^{-1} > F > 10^{-3}$	PCC3 : infrequent accidents	$10^{-2} > F > 10^{-4}$	PC-3	$10^{-1} > F > 10^{-2}$
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H5 (Very improbable events)	$10^{-5} > F$			PC-5	$10^{-4} > F > 10^{-6}$
Extremely improbable events	$10^{-7} > F$				

Homework

Look into examples of events for different PIE categories (slide 16 – 21).

- Reflect, on your own, about these examples, why they belong to the assigned category and which improvement/ could change their categorization
- Discuss this with your groupmates