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# Introduction to JSME Guidelines on Reliability Target Establishment and Conformity Evaluation for Passive Components

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# Scope

- **Risk-informed decision making processes have been primarily applied to plant safety design.**
- **Design and maintenance of passive components, one of the most important factors in reducing plant risk, are mostly performed in a conventional deterministic way.**
- **Embedding structural design of passive components into risk-informed processes more explicitly would allow for decision making further in line with the way it should be.**
- **The JSME guidelines provide a methodology.**

**Plant designer**

**SSC designer**

**Plant safety goals have been set forth!:**

***CDF<a x $10^{-b}$/p-y, and***
***LERF<c x $10^{-d}$/p-y***

**?**

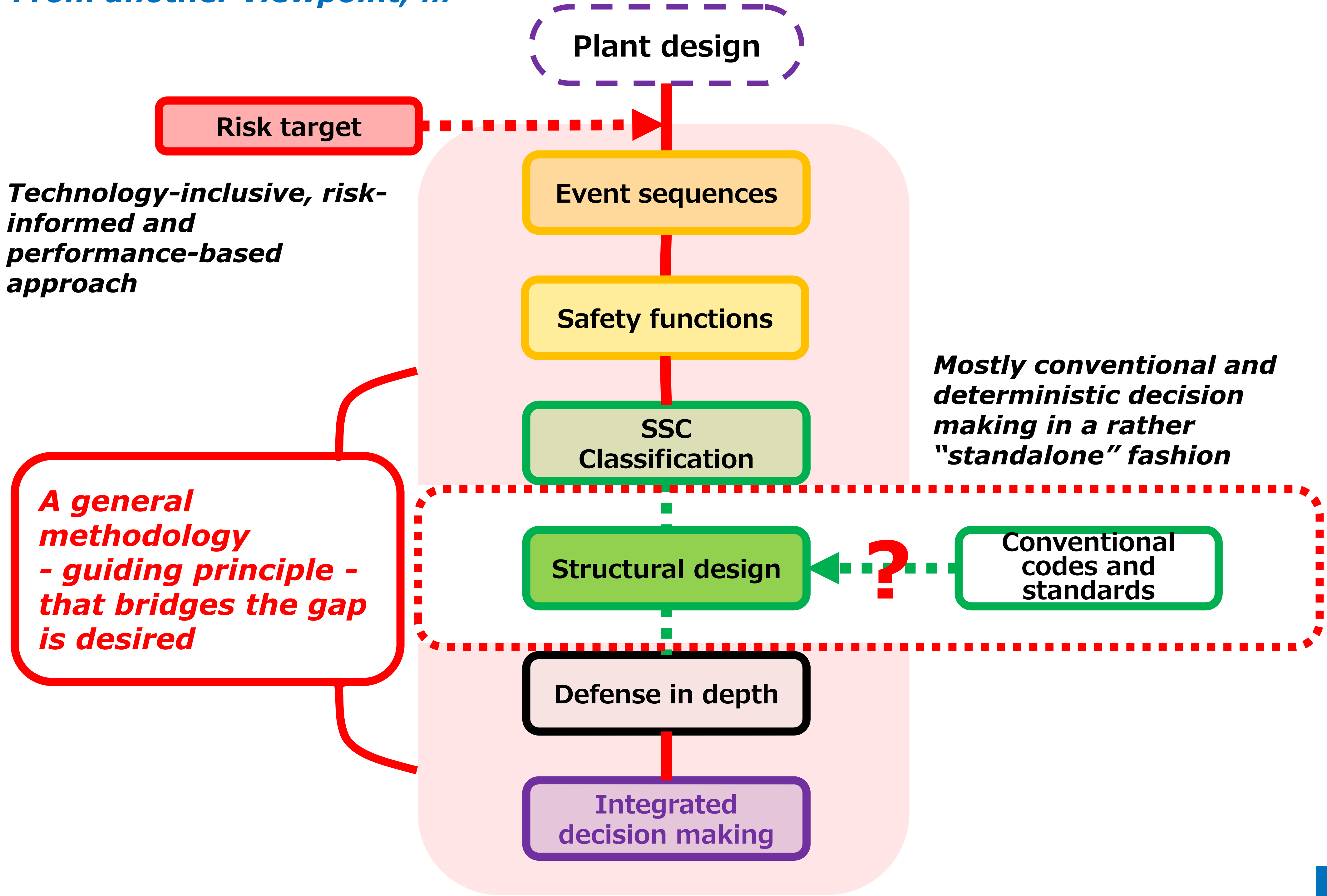
**Then, …, should a failure with this probability be counted as an *Initiating Event*?**

**How can I adjust the *design factors* accordingly?**
***How thick should my vessel be?***

**Does it mean that the *latest* inservice inspection *technologies* are not applicable?**

**Should a *deviation in structural state that does not harm safety* be prevented as a "failure"?**

## *From another viewpoint, …*



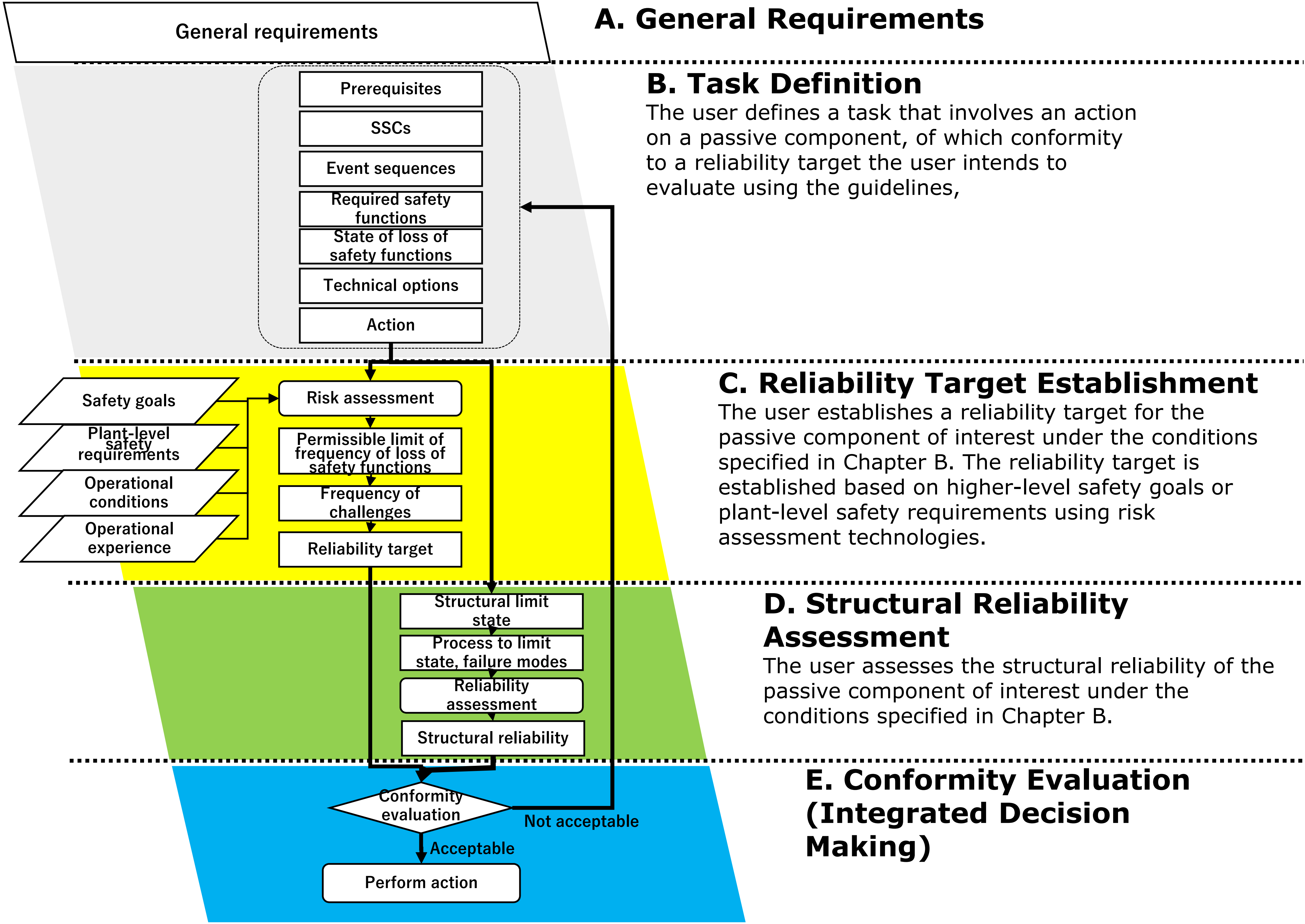
# Preceding work

- **ASME Boiler and Pressure Vessel Code Case N-875**
  - **Introduced the reliability target** **for the first time in the ASME BPVC** as a criterion by which the applicability of alternative inservice insepection requirements – ***something not in the current practice*** - is judged.
  - **An outcome of collaborative efforts of JSME and ASME**. Issued in 2017 to provide alternative requirements to ASME BPVC Section XI Division 3, inservice inspection requirements for liquid metal cooled reactors.

  ✓The basic concepts such as **the reliability target have been implemented in ASME Boiler and Pressure Vessel Code Section XI Division 2, endorsed with conditions by the U.S. NRC** in October 2022 (RG 1.246)

# JSME Guidelines on Reliability Target Establishment and Conformity Evaluation for Passive Components

- **Developed by the JSME TG on Reliability Target established in 2019**
  - ✓ **Chair: Tatsuya Itoi (The University of Tokyo)**
  - ✓ **Member: Utilities, fabricators, engineering firms and research institutions**
- **A general methodology to establish a reliability target, assess structural reliability and evaluate the conformity of the structural reliability to the target**
  - ✓ **Applicable to any conduit over the lifecycle of SSCs**
- **A voluntary umbrella code that can be used with other JSME structural codes**
- **Approved for publication in December 2023**



General requirements
A. General Requirements
B. Task Definition
The user defines a task that involves an action on a passive component, of which conformity to a reliability target the user intends to evaluate using the guidelines,
Prerequisites
SSCs
Event sequences
Required safety functions
State of loss of safety functions
Technical options
Action
C. Reliability Target Establishment
The user establishes a reliability target for the passive component of interest under the conditions specified in Chapter B. The reliability target is established based on higher-level safety goals or plant-level safety requirements using risk assessment technologies.
Safety goals
Plant-level safety requirements
Operational conditions
Operational experience
Risk assessment
Permissible limit of frequency of loss of safety functions
Frequency of challenges
Reliability target
D. Structural Reliability Assessment
The user assesses the structural reliability of the passive component of interest under the conditions specified in Chapter B.
Structural limit state
Process to limit state, failure modes
Reliability assessment
Structural reliability
E. Conformity Evaluation (Integrated Decision Making)
Conformity evaluation
Not acceptable
Acceptable
Perform action

# *Key words*

- **Action**: a technical conduct on the SSC(s) of interest of which conformity to reliability targets is evaluated using the methodology.
- **Structural limit state**: a structural state that corresponds to the **loss of safety function of the SSC(s)**. For example, if the safety function is a coolant boundary function, this state could be defined as a state where penetrated crack(s) exist in the wall of the SSC.
- **Challenges**: attributes that have the potential to cause **the loss of functions of the SSC(s)**. Include loading due to normal operation, internal hazards and external hazards
- **Reliability target**: structural reliability which the SSC(s) needs to maintain for the plant to meet its higher-level safety requirements. Conceptually, derived as a conditional probability to reach the **structural limit state** given **challenges** occurred, from the **permissible frequency of loss of safety functions** and the **frequency of challenges**.

# A. General Requirements

**Purpose**: Provide a methodology for reliability target establishment and conformity evaluation for passive components. The methodology is called “Reliability Target Design methodology”.

**Scope**: Applicable irrespective of reactor type, under design and in operation. Applicable to whole or part of the SSCs of the plant, and whole or part of its lifecycle.

**Positioning in the JSME Codes for Nuclear Power Generation Facilities**: The guidelines will be a non-mandatory umbrella code that will be used in combination with existing JSME Codes for Nuclear Power Generation Facilities

# B. Task Definition

**The user defines a task which involves an action that the user intends to justify using the guidelines**

✓**Prerequisites:** norms with which the user intends to comply when performing an action. Regulatory requirements, consensus codes and standards, and quality assurance programs, etc.

✓ **SSCs:** Both those on which an action is performed and of which safety functions may be affected by the action.

✓ **Event sequences:** both those which directly involve the SSCs of interest and those which do not involve them but could be affected by the action.

✓ **Required safety functions and the state of loss of functions:** those that the SSCs need to perform to make the plant meet its higher-level safety requirements and the status in which they are lost.

✓ **Technical options:** those that are not in existing codes and standards may be employed. The selection among them is at the user's discretion.

✓ **Action:** a technical conduct on the SSC(s) of interest of which conformity to reliability targets is evaluated using the methodology.

# B. Task Definition – *Example*

**Design a fast reactor's reactor vessel (RV) and guard vessel (GV)**

**Action**

Design a vessel (RV) and guard vessel (GV) with configurations and inspection strategies that partially deviate from consensus codes and standards due to the adoption of novel technologies

**Prerequisites**

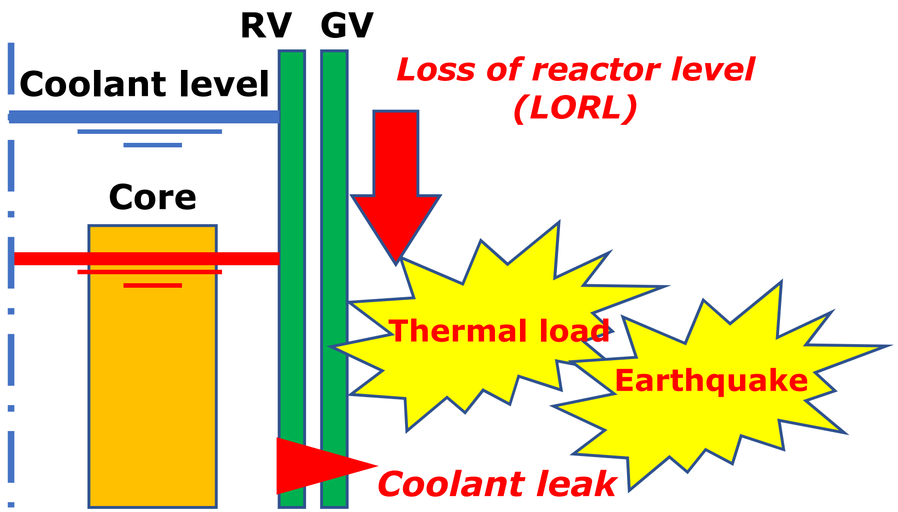
- Regulation
- Consensus codes JSME, ASME
- Quality assurance requirements

With deviations

**SSCs**

**Event sequences**

**Required safety functions**




**Technical options**

Operating temperature, number of start-ups and shutdowns, materials, configurations, design factors, welding methods, etc.

# C. Reliability Target Establishment

**The user establishes a reliability target for the SSC of interest based on plant safety requirements**

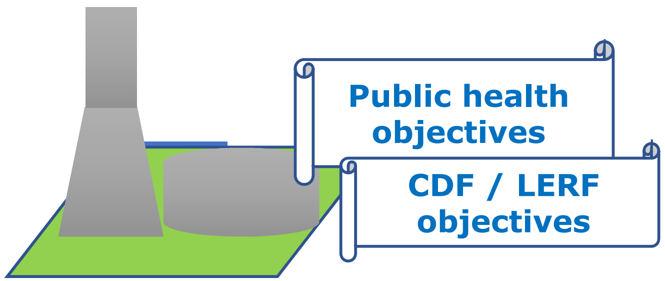
**<Sub step 1> The user refers to higher level safety requirements or selects alternative indices to establish a reliability target;** the guidelines do not specify higher level requirements or alternative indices. Selection is at the user's discretion.

**<Sub step 2> The user derives a permissible limit of frequency of loss of function the component of interest** using a risk assessment method of the user's selection; then, **the user derives a reliability target based on the frequency of challenges and the permissible limit of frequency of loss of function;** quantitative, semi-quantitative or qualitative method can be used for risk assessment.

- ✓ Mathematically, a reliability target is "***one minus the conditional failure probability of the component given that the postulated challenges have occurred, which, when multiplied by the frequency of challenges, equals to the permissible limit of the frequency of loss of safety function***". However, semi-quantitative or qualitative setting can also be used.

# C. Reliability Target Establishment – *Example*

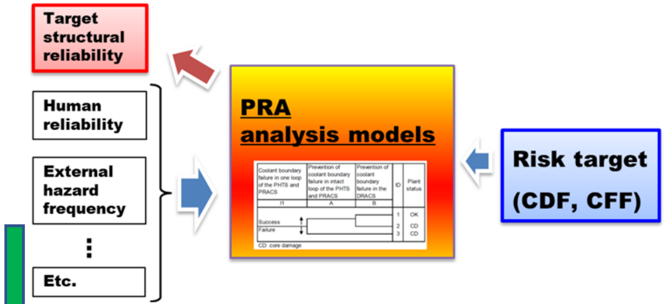
**Higher level safety requirements**




Refer to objectives on core damage frequency for advanced reactors

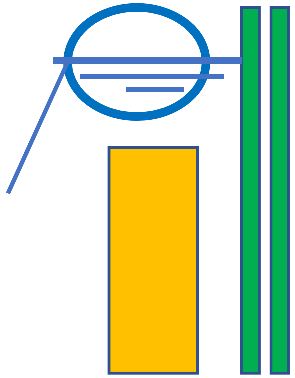
**Risk assessment method**

Use probabilistic risk assessment methodologies to take account of whole plant dynamics




**Permissible frequency of loss of function**

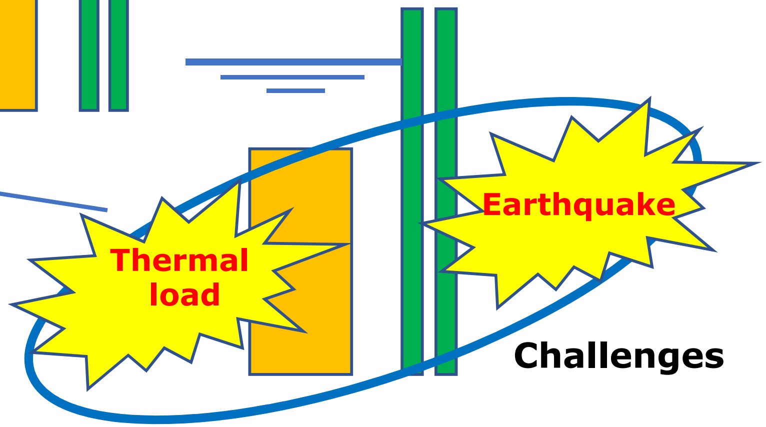
Derive permissible frequency of loss of coolant under "*LORL" considering all the other event sequences* that may cause core damage



Event: *Loss of reactor level (LORL)*

**Frequency of challenges**

Estimate frequency of challenges




**Reliability target**

Derive a reliability target based on the permissible frequency of loss of function and the frequency of challenges

# D. Structural Reliability Assessment

**The user assesses the structural reliability of the SSC with the action implementation assumed**

**<Sub step 1> The user identifies conditions for structural reliability assessment. Major ones are the following:**

- ✓Definition of structural limit state
- ✓All potential paths to reach the structural limit state and associated failure modes
- ✓Mechanical and/or chemical models that represent the above

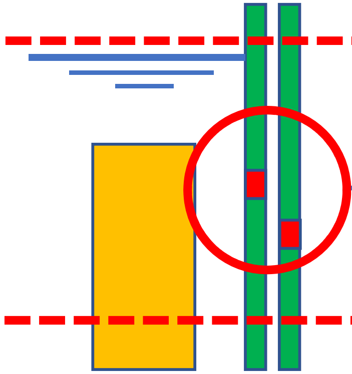
**<Sub step 2> The user chooses a structural reliability assessment method;** Theoretical methods such as the LRFD method as well as empirical methods that take advantage of operational experience can be used.

**<Sub step 3> The user performs structural reliability assessment.**

- ✓Empirical, analytical or numerical method including combination
- ✓Quantitative, semi-quantitative or qualitative

# D. Structural Reliability Assessment - *Example*

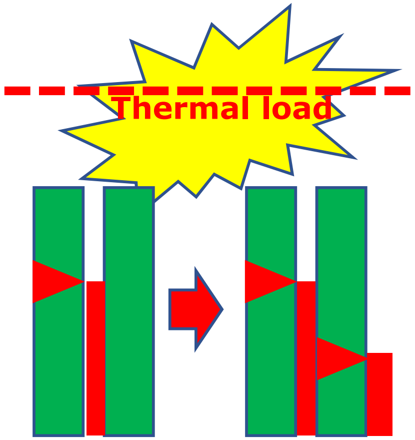
**Structural limit state**



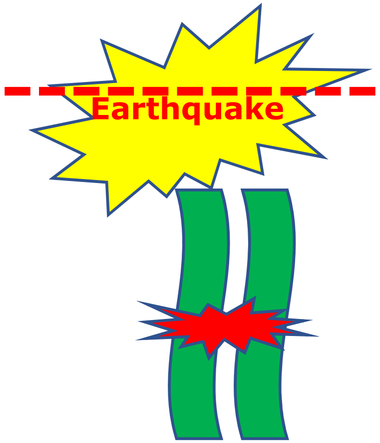
Define structural limit state as emergence of through wall openings that lead to loss of coolant

**Paths and failure modes**

Consider all paths and failure modes that lead to the structural limit state




Initiation and propagation of cracks (creep-fatigue)



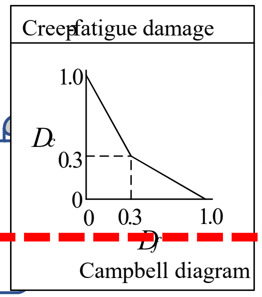

Boundary fracture (buckling)

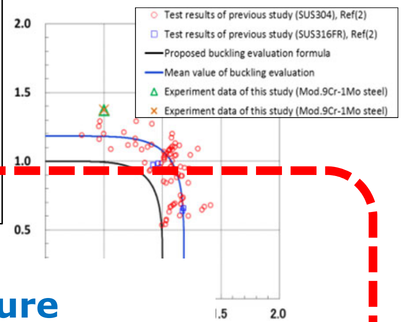
**Modeling**

Construct mechanical models to estimate structural reliability

Consensus codes JSME, ASME

Novel technologies

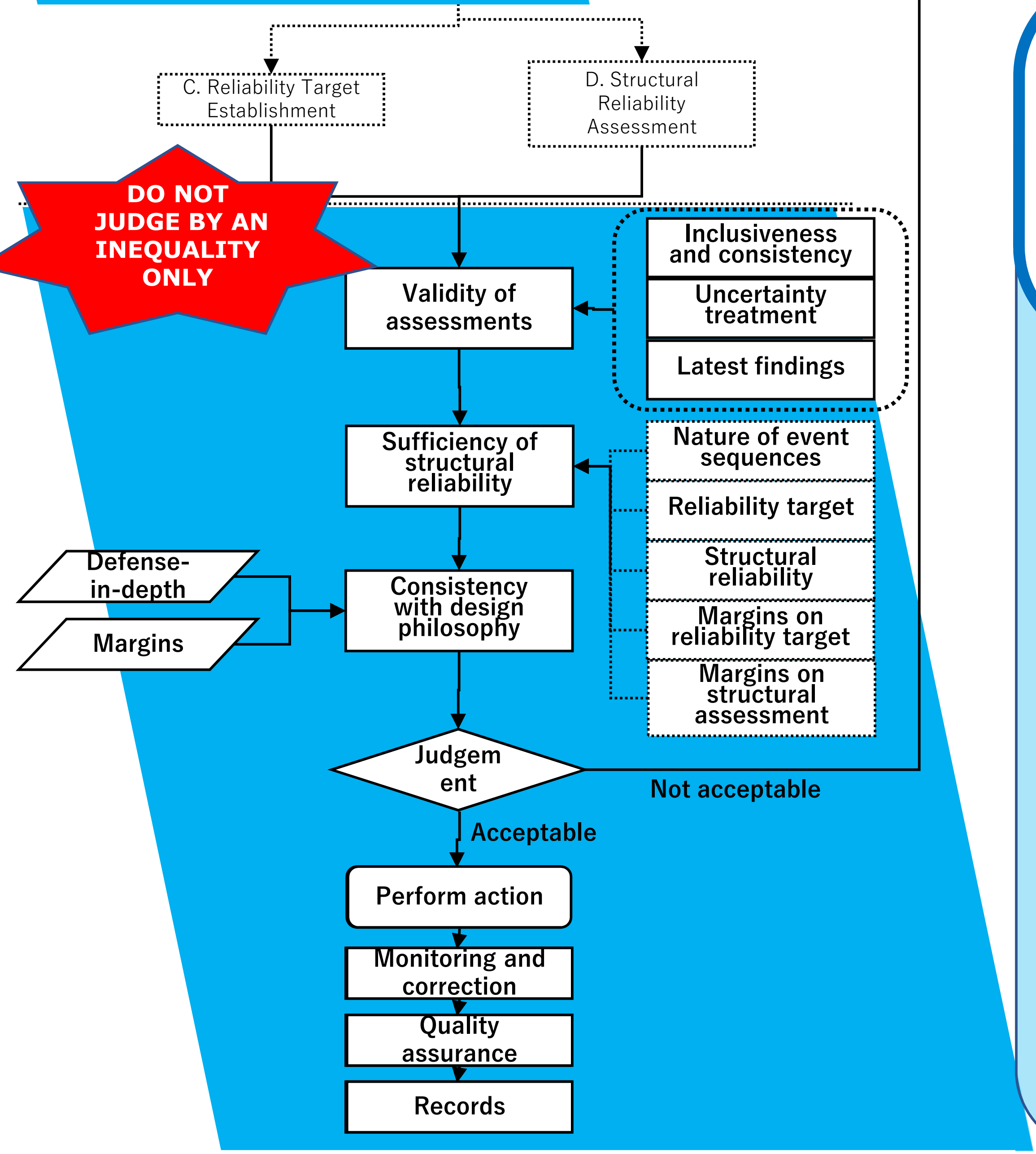



**Structural reliability**

Estimate structural reliability as the conditional failure probability given the challenges occurred

# E. Conformity Evaluation (Integrated Decision Making)




**The user evaluates the conformity of the structural reliability to the target reliability in an integrated decision making framework**

**The evaluation is performed in an integrated fashion, not by comparing numerical values but also by ensuring the following:**

1. Validity of assessments:
2. Sufficiency of structural reliability considering associated uncertainties:
3. Consistency with the design philosophy of nuclear power plants, i.e., defense-in-depth and maintaining margins:

**If all of the above are sufficient, the action is permitted**

# E. Conformity Evaluation (Integrated Decision Making) – Cont'd

## 1. Validity of assessments:

- **Inclusiveness and consistency**:
  - ✓**Inclusiveness**: all event sequences and SSCs which may impact and may be impacted by the action defined in Section B are included in the defined task.
  - ✓**Consistency**: technical options, the state of loss of safety function and structural limit state, and uncertainties are treated in a consistent manner throughout the process
- **Uncertainty treatment**:
  - ✓**Aleatoric**: should be accounted for by representing technical options with non-negligible uncertainties by probabilistic variables.
  - ✓**Epistemic**: completeness, parameter, and model uncertainties should be accounted for appropriately
- **Consistency with latest technical findings**:
  - ✓Consistency with the latest R&Ds
  - ✓Consistency with  and operational experience

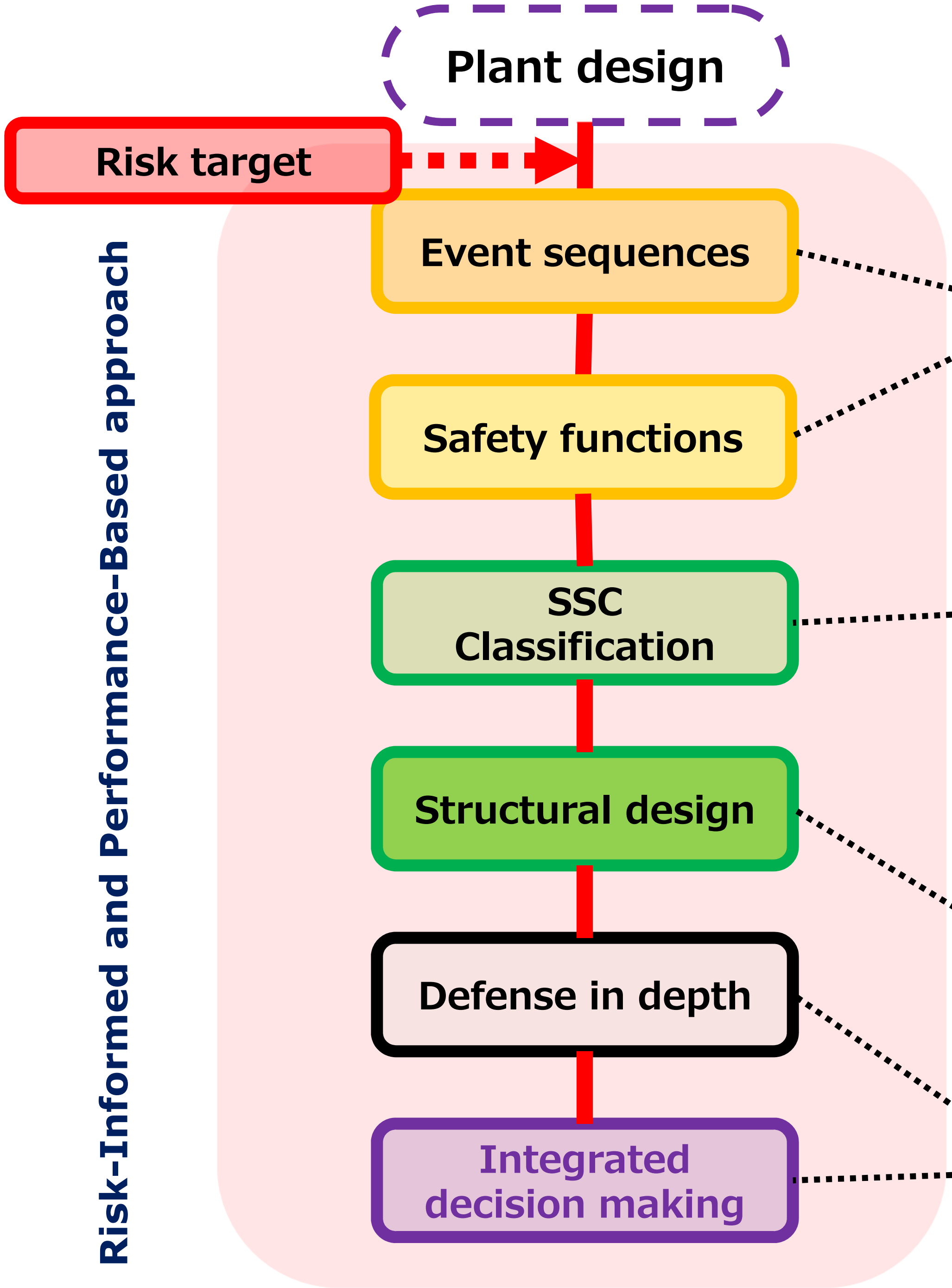
## 2. Sufficiency of structural reliability:

- **Nature of event sequences**: Frequency, Consequence, Rapidness, Stability (the presence or absence of cliff-edge effects), Detectability and possible mitigation
- **Margin allocation**: margins on reliability target and margins on structural assessment

## 3. Consistency with the design philosophy of nuclear power plants:

- **Defense-in-Depth**: The user refers to relevant definitions of DiD and makes sure the concept is maintained when the action is performed
- **Overall Margins**: The user reassures that the margins are sufficient in light of factors not considered in the precedent procedures.

**Now, the gap has been bridged.**




## JSME Guidelines on Reliability Target Establishment and Conformity Evaluation for Passive Components

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### C. Reliability Target Establishment

The user establishes a reliability target for the passive component of interest under the conditions specified in Chapter B. The reliability target is established based on higher-level safety goals or plant-level safety requirements using risk assessment technologies.

### D. Structural Reliability Assessment

The user assesses the structural reliability of the passive component of interest under the conditions specified in Chapter B.

### E. Conformity Evaluation (Integrated Decision Making)

# Concluding remarks

- **JSME developed new guidelines "Guidelines on Reliability Target Establishment and Conformity Evaluation for Passive Components".**
- **The guidelines provide a general methodology to embed structural design of passive components into risk-informed processes to allow decision making to be further in line with the way it should be.**
- **The methodology is technology-inclusive, risk-informed and performance-based.**
- **More detailed guidance alongside some worked examples is being elaborated in JSME for the next version of the guidelines.**

**Thank you for your attention.**