Application of PSA Developed in Nuclear Industries to Other Industries

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Contents

I. Introduction

I-1. Terminology

1. PSA

- PSA, Probabilistic Safety Assessment
  = PRA, Probabilistic Risk Assessment (usually used in U.S.)
  = QRA, Quantitative Risk Analysis (used in general industries)

- Safety
  - Condition free from harm or risk
- Risk
  - Possibility of loss of injury
  - Risk = Frequency x Consequence

I-2. Objective

1. Objective

- To introduce the method of how to efficiently improve the safety of the complex system

2. Scope

- Checking the potential applicability of PSA developed in nuclear to PSA in the other complex systems.

I-2. History of PSA

1. **PSA in Aerospace**

- Methods to perform risk assessment in the early 1960s originated in U.S. aerospace and missile programs.

- Early in the Apollo project, the question was asked about the probability of successfully sending astronauts to the moon and returning them safely to Earth.
  A risk calculation was performed and the result was a very low success probability value.

- NASA became discouraged from further performing quantitative analyses of risk, and gave up PSA.

I-2. History of PSA

2. PSA in NPPs : WASH-1400

- The nuclear industry picked up PSA to assess safety.
- In 1975, the first modern PSA, the Reactor Safety Study (WASH-1400), for nuclear power plants (NPPs) was completed.
  - Its purpose was to quantify the risks to the public from NPPs.
  - BUT, significant controversy arose about a result of WASH-1400.
- Some remained skeptical on the practicality of WASH-1400 until the accident at Three Mile Island 2 (TMI-2) in 1979.

3. PSA after TMI-2

- Following the severe core damage event at TMI-2, application of PSA gained momentum within the nuclear safety community.
  - PSA-used re-examination of the allocation of licensee

- In the 1980s, PSA has been used for safety analysis of NPPs.

- In the 1990s and beyond, regulation itself is being changed to refocus attention on safety improvement.

II. Why PSA?

II-1. Importance

1. **Decision Support Tool**

- PSA is a comprehensive analysis method aimed at identifying and assessing risks in complex systems for the purpose of cost-effectively improving their safety and performance.
  - To provide insights into the nature of the facility that is being managed,
  - To design defense-in-depth,
  - To understand any issues that require further investigation.

II-2. PSA in Nuclear

1. **Two approaches for nuclear safety**

- Deterministic approach : If it happens, it must not matter.
  - Defense-in-Depth
  - Safety margins

- Probabilistic approach : If it matters, it must not happen.
  - PSA (including risk-informed activities)

II-2. PSA in Nuclear

2. Probabilistic approach

- Aim of PSA
  - To identify combinations of failures that will cause safety barriers of a NPP to fail
- PSA process

1) Accident Frequency Analysis
   - Human error, Component failure

2) Accident Progression Analysis
   - Initial event → other systems or components

3) Risk Source-Term Analysis
   - Evaluation on the characteristics of source-term

4) Off-site Analysis
   - Appraisal of environmental influence due to source-term

5) Risk Calculation
   - Overall risk of the facility

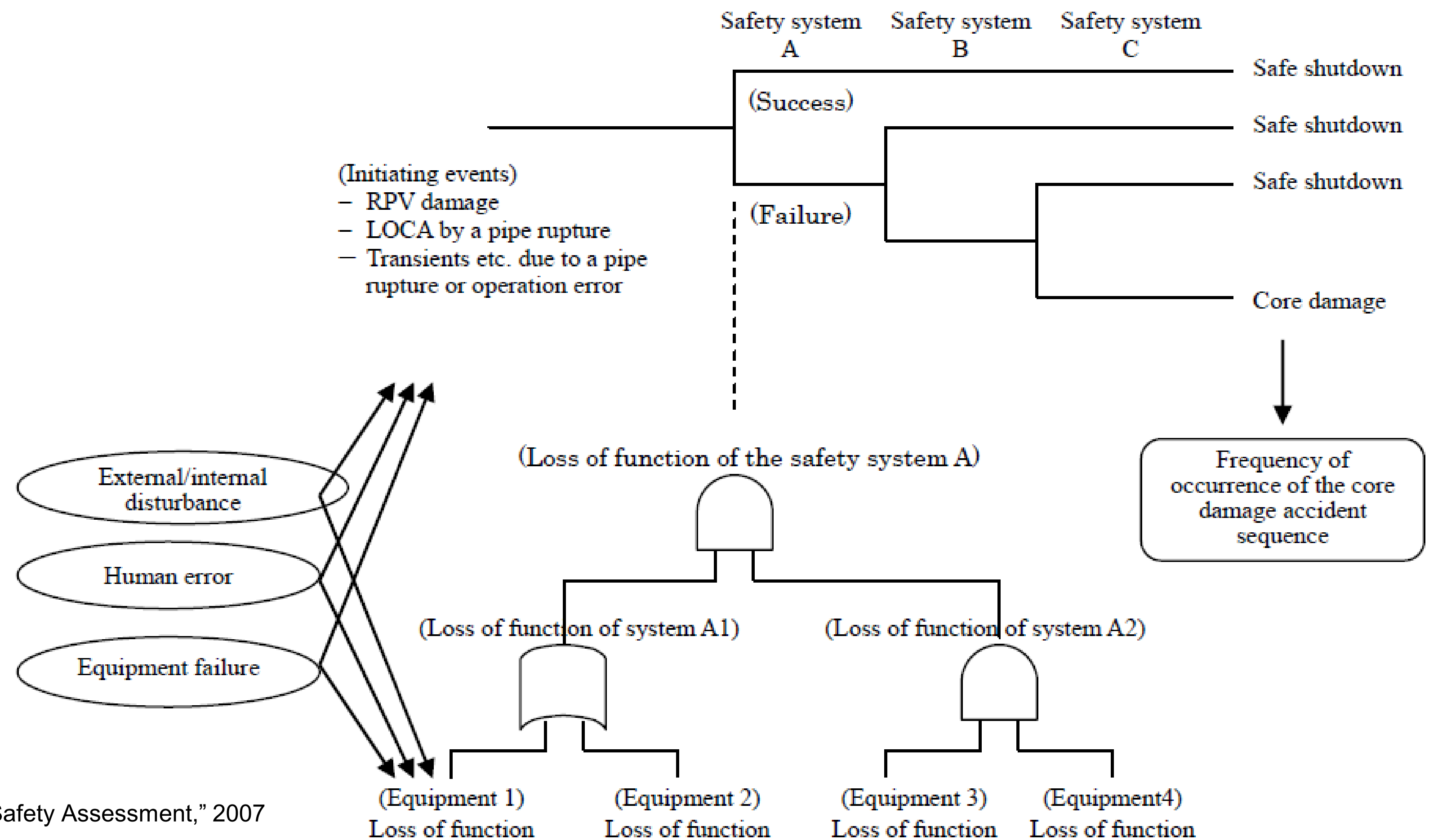
Level 1 : Core damage

Level 2 : Release from the containment

Level 3 : Health effects

II-2. PSA in Nuclear

- Methodology
  - Evaluation of Risk through Event tree & Fault tree
    - e.g. Level 1PSA

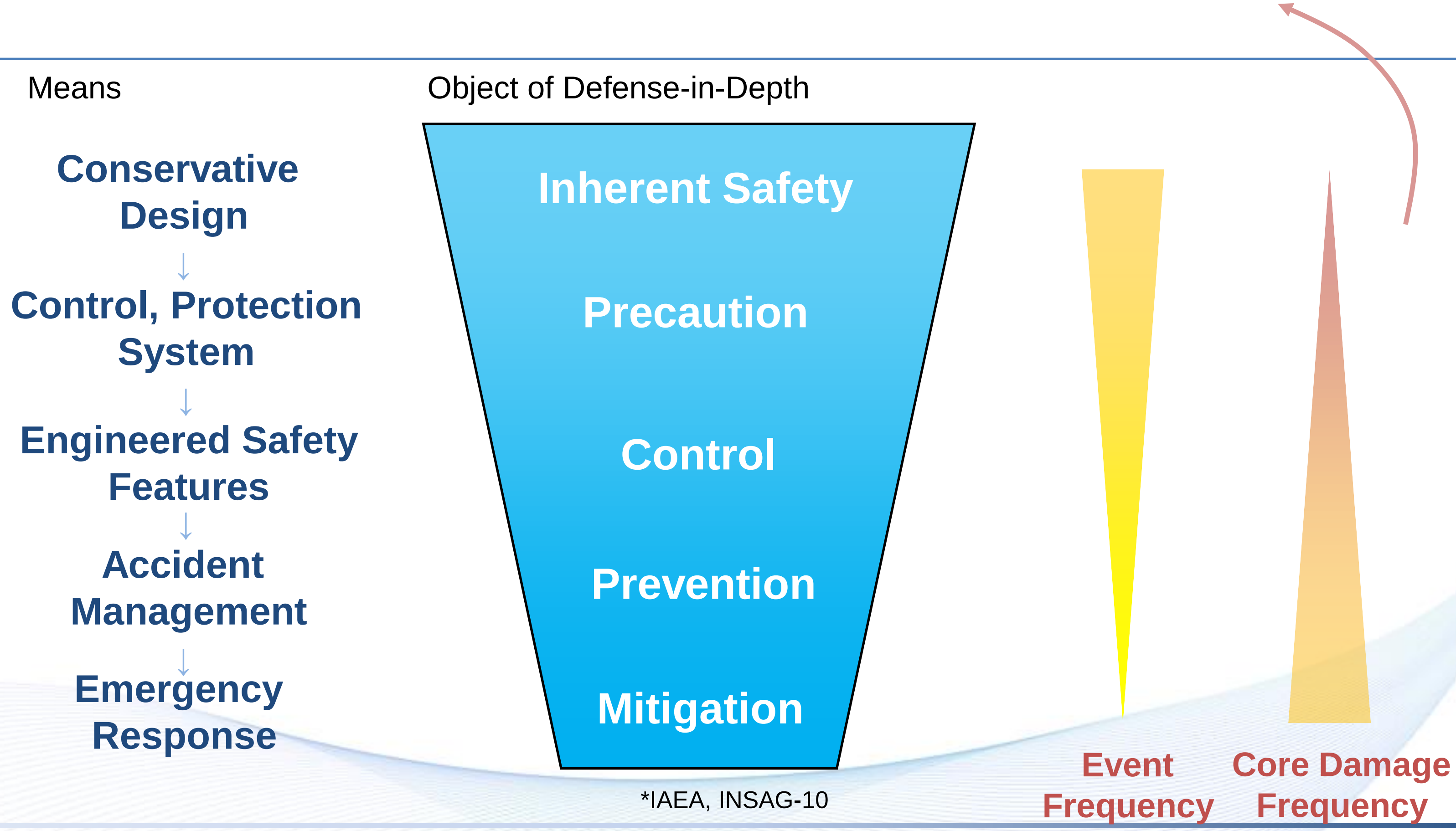


* JNES, "Probabilistic Safety Assessment," 2007

II-2. PSA in Nuclear

3. Combination of Deterministic and Probabilistic approach

- Evolution of PSA → **Risk-Informed** or **Risk-Based**
- **Safety criteria** reasonably made with **Event Frequency** and **CDF**



*IAEA, INSAG-10

II-2. Meaning

1. **Output**
   - Quantitatively anticipated risks
   - Detection of weak points of design

2. **Outcome**
   - Risk is reduced in two ways:
     - by making an undesirable event less likely, or
     - by making its consequence less serious.
   - Nuclear industries can practically ensure safety through design, control, and regulation.
   - Security based on safety is reinforced.

3. PSA & Fukushima accident

- PSA revealed the importance of dealing with the followings:
  - Station Black-Out → EDG (Emergency Diesel Generator)
  - Hydrogen Explosion → PAR (Passive Auto-catalytic Recombiner)
  - Continuously Counting External Events
    - Several hazards including **tsunami** were not covered by older PSA.

- If all NPPs would have accepted the results of PSA,
  the Fukushima accident would be downscaled or never happen.

The Fukushima accident shows that the use of PSA can prevent an accident itself, or at least mitigate the consequences of an accident.

III. Challenge & Limitation

III-1. What to be considered

1. **Dependency on applications**

- PSA starts from answering the questions:
  1) What can go wrong?
  2) How likely is it?
  3) What are the consequences?

- In addressing these questions, there are a number of differences in the way the nuclear, petrochemical, and rail industries go about their PSAs.
  - These differences tend to be shaped by the risk criteria, technology involved, the nature of the hazard itself corresponding to each industry.

- PSA within NPP is not necessarily optimal for other industries.

III-1. What to be considered

2. Capability of PSA practitioners

- Because PSA involves lots of practitioner's judgments throughout the analysis, the results could not appear to be objective.
- Some judgments are explicit but many more are hidden within data and methods.
- It is the role of the practitioners to interpret results in the context of the uncertainties inherent within the analysis.

III-2. Limitation

- Lack of reliable database in specific areas
  - To conduct PSA requires credible databases for reliability and failure of the facilities.
- Uncertainties regarding data
- Influence of human factors.
- Theoretical modeling may not reflect actual operations.

IV. Application of PSA in Industries

IV-1. NPP

- In the world, nuclear industry has achieved on the application of PSA from nuclear plant design to operation, maintenance.

- A PSA approach to regulation extends the traditional deterministic approach, and enhances safety by allowing the designer and operator to focus on more important issues.
    - For example, US-Nuclear Regulatory Commission (NRC) introduced risk-informed decision-making, which is the advanced type of PSA, into the regulatory process.

- The potential applicability of PSA developed in nuclear to PSA in the other complex systems is proven.

IV-2. Space shuttle

- By the time the Challenger accident occurred in the late 1980s, PSA had become a useful and respected tool for safety.

- In U.S., NASA used PSA in all of its programs and projects to support optimal management decision for the improvement of safety and program performance.

- NASA is now beginning to apply PSA to early in the product life cycle to improve design.

IV-3. Chemical plant

- While both chemical and nuclear hazards are of concern with respect to the public, the more significant safety issues may often lie with the chemical hazards rather than with the nuclear.

- In French, recently a new law for chemical plants was proposed by the government asking for the investigation of all representative scenarios and the assessment of the probability of the resulting dangerous phenomena to demonstrate an acceptable level of safety.

- In order to solve this issue, researches develop the benefits of applying PSA used in the nuclear field to the chemical industry.

  (C. Charvet at el., "Learning from the application of nuclear probabilistic safety assessment to the chemical industry", Journal of Loss Prevention in the Process Industries, 2010)

IV-4. Rail

1. **UK**
   - The rail industry started PSA in the early 1990s, against a background of train accidents, including the Clapham Junction crash in 1988.
   - The rail industry is using PSA more and more, applying it to increasingly complex situations to obtain a greater understanding for important risk-based decisions.

   (Newsletter, "Quantitative Risk Assessment Across Major Hazard Industries," RISKworld, issue13, 3-4, 2008)

2. **Korea**
   - The evaluation on the risk of railway has been attempted by PSA since 2000s.
   - Researchers wanted to develop a risk assessment tool for the maintenance and control of the railway risk model.

   (Lee, H.J. et al., "Development of Integrated Method and Tool for Railway Risk Assessment", the Korea Society for Railway, Vol.6, 2006)

V. Conclusion

V. Conclusion

1. By using PSA, NPP can quantitatively anticipate risks, and practically ensure safety through design, maintenance, and regulation.

   → The Fukushima accident shows that the help of PSA can prevent an accident itself, or mitigate the consequences of an accident.

2. PSA developed in nuclear to PSA has the potential applicability to PSA in the other complex systems for improving safety.

   → PSA was successfully used in chemical plant, rail, space shuttle for safety.