Risk Management Strategy for Uncertain Systems: Decommissioning of Fukushima Daiichi Nuclear Power Station

Presented by

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Research Objective

- Establishment of risk management strategy
  - Decommissioning of Fukushima Daiichi Nuclear Power Plant Decommissioning
- Uncertain systems
  - First of a kind / New system – Little experience
  - Complex system – System of systems
  - Low frequency but high consequence
  - Various types of scenarios
  - Public trust is important
- Risk understanding & management

Fukushima Daiichi Accident

- The seismic-induced mega-tsunami on March 11, 2011 resulted in reactor core melt in three units of the Fukushima Daiichi Nuclear Power Station (FD-NPS)
- A few thousands of fuel assemblies were left in spent fuel pools (SFPs) of four units which reactor buildings were seriously damaged and contaminated by the release of radioactive materials and/or hydrogen explosion.
- Risks in terms of safety and security, in technological as well as social aspects


15:42, Mar.11
15:43, Mar.11
15:46, Mar.11
15:57, Mar.11

Testimonies of Accident Witness
Initiation of Nightmare

- After this (around when the tsunami arrived), power lights began to flick, and then I saw they all turned off.
- The emergency power was shut off, and all of the lights on the MCR panel started to turn off. I did not know what happened however I couldn't figure out that it was caused by a tsunami.
- My fear were confirmed when operator was running into the MCR and yelling we're being flooded with sea water.

Air Photo Service （March 20）

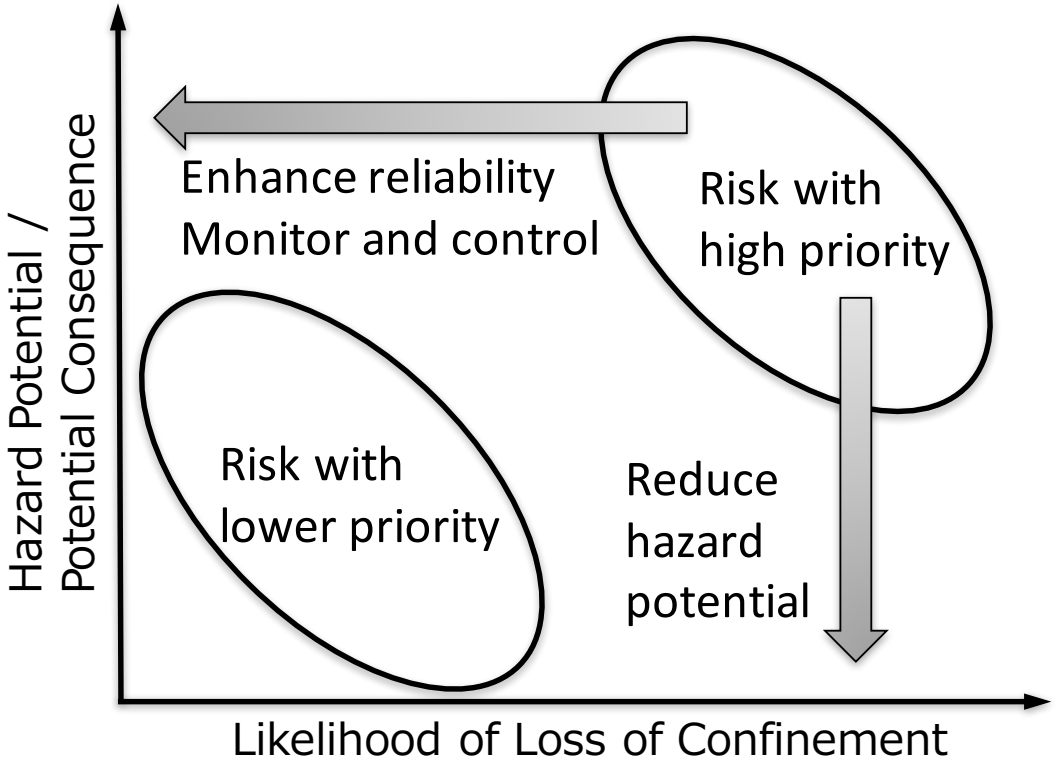
Risk Management Goal

- To control and reduce the risk of the FD-NPS so that the public and workers are not exposed to significant radiation and radioactive materials are adequately confined.
- It is achieved by
  - Removal of hazard potential on the site.
    - Temporary risk increase
  - Optimized decision-making by balancing advantage and disadvantage, and cost and benefit

Risk Management in Decommissioning

- Decommissioning of the FD-NPS
  - Fuel debris in containment vessels
  - Fuel assemblies in the spent fuel pools (SFPs)
  - Contaminated water
  - Other solid wastes
- Risk characteristics are significantly different from those in an operating nuclear power plant
- Appropriate risk assessment strategy is needed
  - Understanding of the risk characteristics
  - Assigning priorities on individual tasks

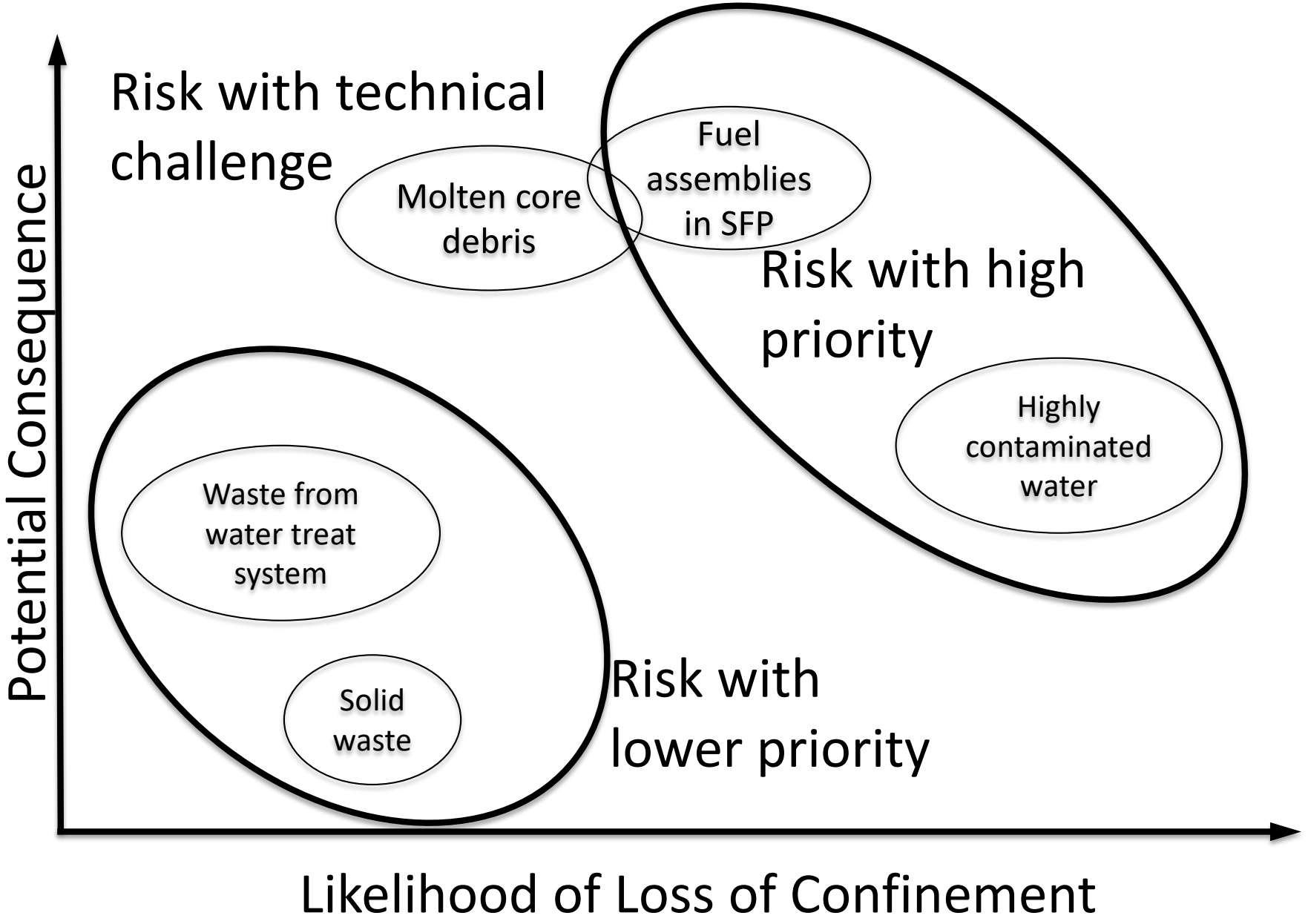
Risk Reducaiton Strategy



Risk with high priority
- Fuel debris
- Fuel assemblies in SFPs
- Contaminated water in buildings

Risk with low priority
- Fuel in common pool/dry cask
- Solid waste
- Waste sludge, etc.

Potential Risk Source at FD-NPS.



Risk Metrics

- Three risk metrics
  - Labor safety
  - Nuclear safety
  - Project accomplishment
- Different kind of risks
  - Safety and health of public and workers (technological risk)
  - Loss of public trust (societal risk)
  - Lack of financial support and delay in schedule (project risk)

Four Principles of Risk Assessment

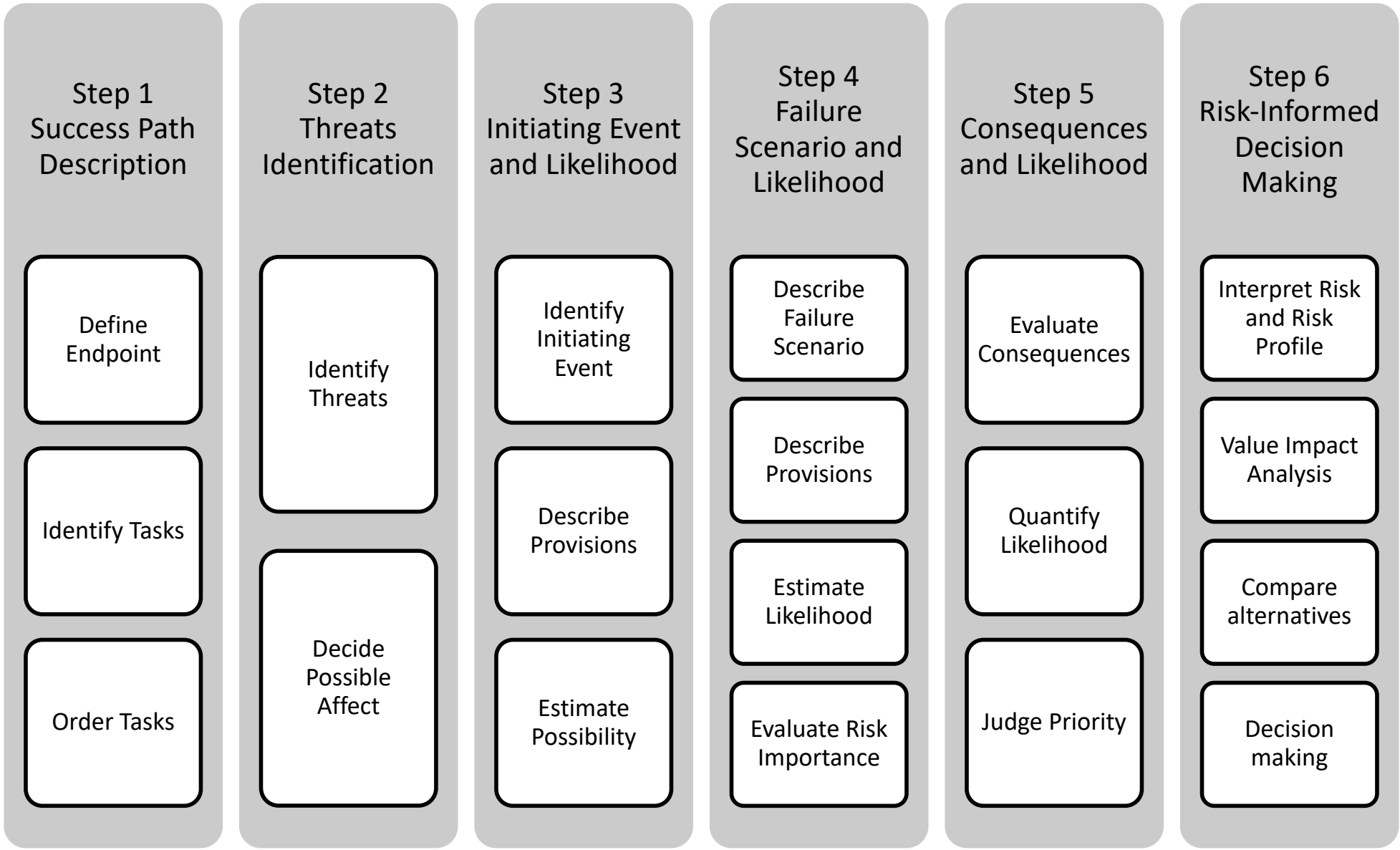
- Comprehensiveness
  - All the possible scenarios are taken into consideration
- Efficiency
  - Risk assessment is performed with reasonable cost and resources
- Measurability
  - Risk is defined and evaluated as measurable quantities
- Effectiveness
  - Effective and practicable risk management provisions can be proposed

Definition of Endpoint

- The Technical Strategic Plan 2016 (NDF*)
  - to reduce the nuclear radiation risk continuously as well as promptly
  - to make a steady progress in decommissioning on a mid- and long-term basis”
- Five basic concepts of the decommissioning are:
  - Safety
  - Reliability
  - Efficiency
  - Promptness
  - Field-oriented

* Nuclear Damage Compensation and Decommissioning Facilitation Corporation

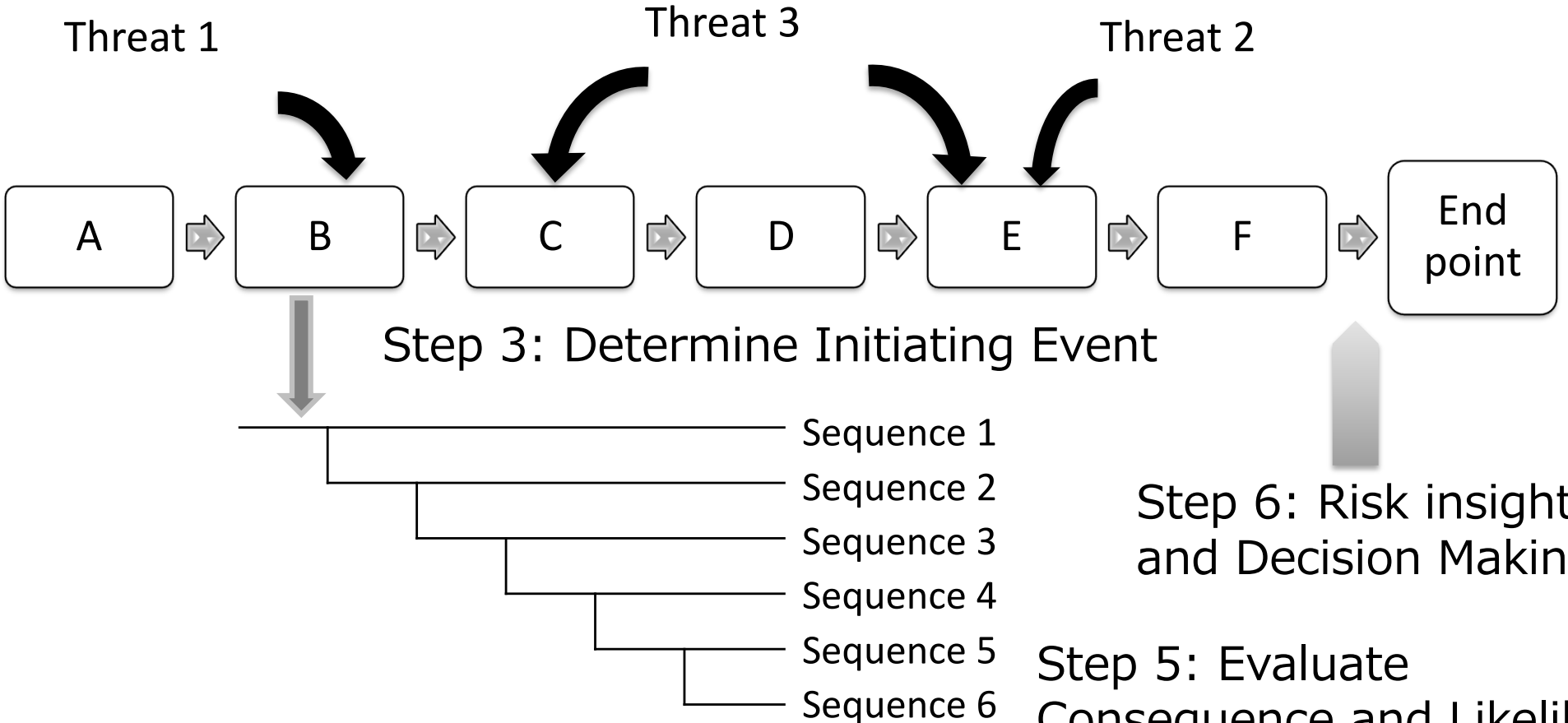
Risk Assessment Strategy



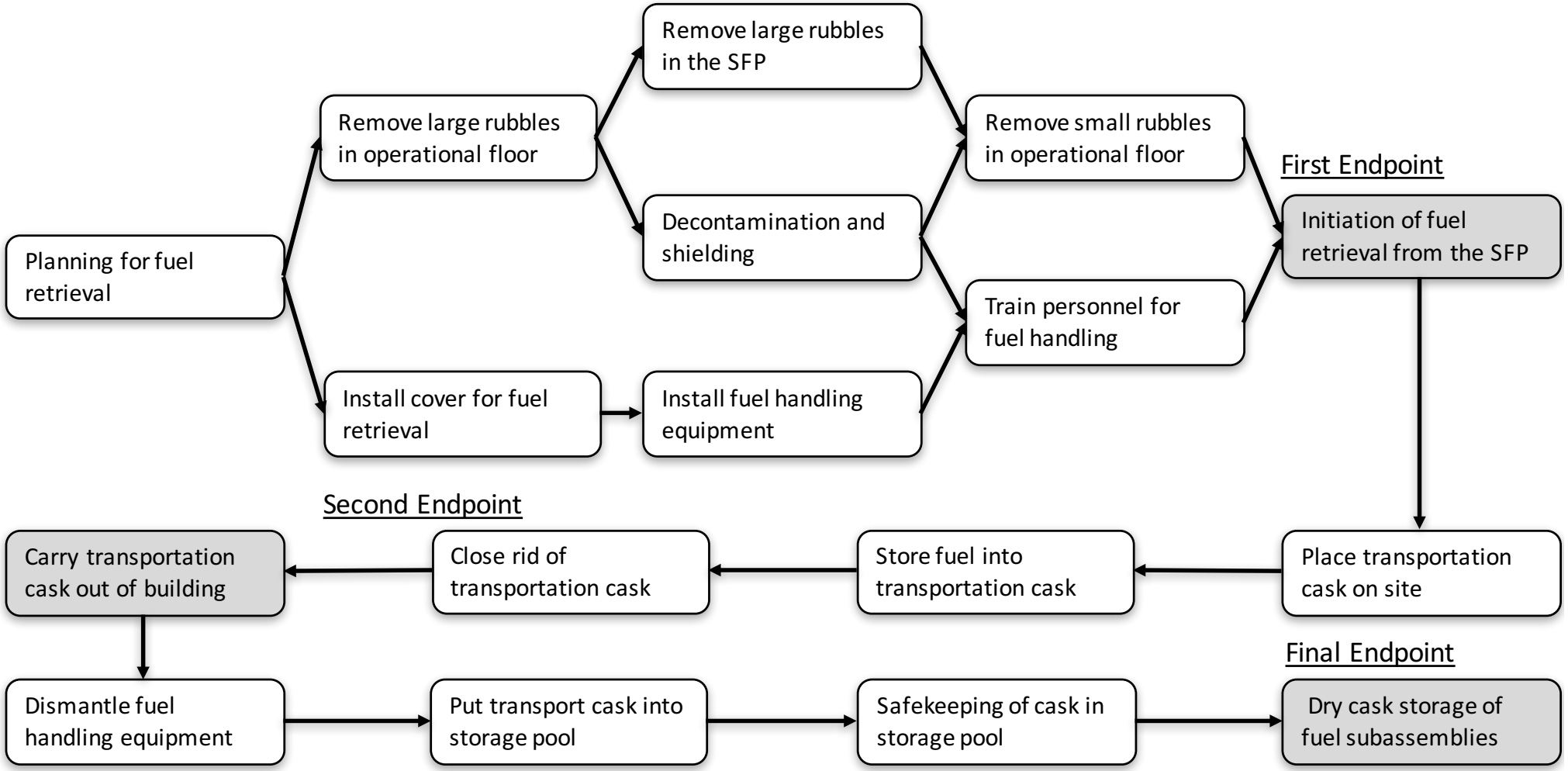
Six Steps of Risk Management

Step 1: Describe the success path

Step 2: Identify threats to each success path element



Multi-Phase Process with Multiple Endpoints
SFP Fuel Retrieval Work in Unit 3



Steps 1 and 2: Combination of Success Path and Threats (Initiator)

Element of success path		Threat: System and Equipment Factor			Societal Factor		Management Factor
		Random failure	Natural hazard	Human error	Public trust	Malicious activity	Project management
Sub-Endpoint	*Task*	Loss of power supply					
Fuel Retrieval from Spent Fuel Pool	Transport Fuel using Fuel Handling Machine		Earthquake (Small)				
			Earthquake (Large)				
			Typhoon / Strong wind				
				Miss operation			
					Report minor incident		
						Sabotage	
							Lack of workers

Step 3: Identification of Initiating Events

Step 3: Initiating Event (IE Likelihood)		
Initiating Event Description	Countermeasure and Reasoning of Likelihood	Likelihood (H/M/L/VL)
Combination of the task and threat, possible initiating event	Built-in countermeasures are considered. likelihood is evaluated with reason The reason will be used in the peer review that follows	H (high), M (medium), L (low) and VL (very low). Initiating events VL are screened out

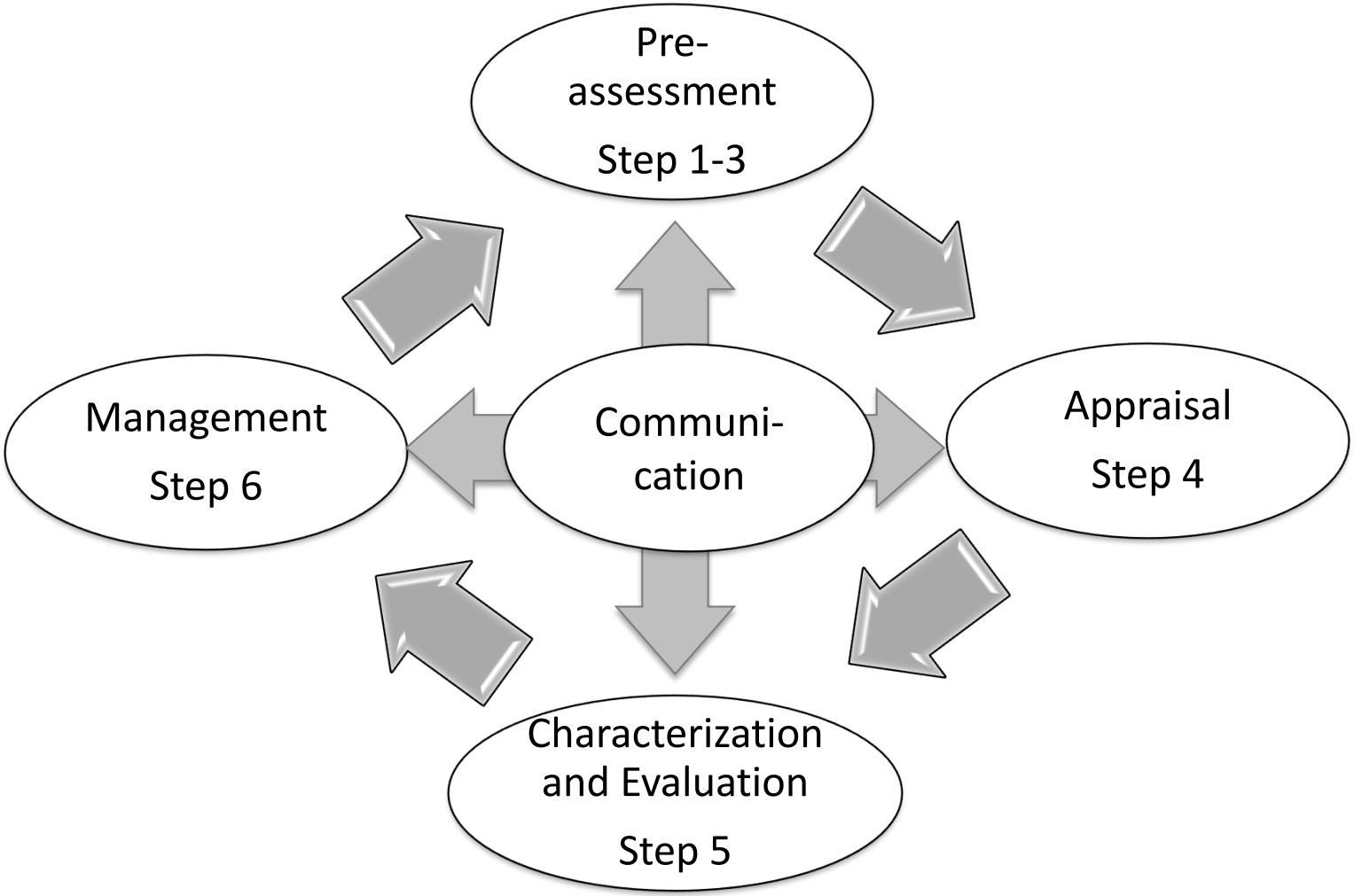
Step 4: Failure Scenario Evaluation

Step 4: Failure Scenario (Scenario Likelihood and Risk Importance)			
Failure Scenario	Scenario Quantification and Reasoning of Likelihood	Likelihood (H/M/L)	Risk Importance
System failure scenario analysis System analysis methods (ET/FT, Graph)	Considering mitigation measures event development (scenario) is listed up Likelihood of the scenario is evaluated with reason The reason will be used in the peer review that follows	H (high) M (medium) L (low) Consider mitigation measures	H (high/unknown) L (low). Failure scenarios od rank L are screened out

Step 5: Prioritization of Failure Scenario

Step 5: Scenario Prioritization		
Consequence	Likelihood (H/M/L)	Priority
Consequence of failure scenario is evaluated in detail Possible measures	Likelihood of failure scenario and consequence is evaluated in detail	With the consequence and likelihood, priority(1-10) is determined

Risk Governance Framework by IRGC



International Risk Governance Council, An introduction to the IRGC Risk Governance Framework, ISBN 978-2-9700772-2-0, 2012

Quantification Method

- Selection of task
  - Transport and Storage Fuel
- Selection of 10 Experts
  - 2 Utility engineers
  - 1 Regulator
  - 1 Risk analyst
  - 2 University professors
  - 2 Vendor engineers
  - 1 Decommissioning company engineer
- 118 Scenarios have been evaluated independently
  - Ranking 1(least importance) to 10 (highest importance)

Conclusions

- Risk management strategy for uncertain systems is proposed
  - Project goals (endpoints) and success path
  - Risk sources and threats
  - Principles and procedures of the risk assessment
  - Endpoint and risk metrics
  - Risk assessment and management procedures (Prioritization)
- The framework is applied to the decommissioning of FD-NPS