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A Risk Management Framework for Reducing the Complex Risks Associated with the Nuclear Fuel Cycle

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Bottom Line Up Front…

Problem

- Increasing complexity managing risk in the Nuclear Fuel Cycle
- Overlaps and possible gaps in risk mitigation responsibilities
- Conflicting objectives

Proposed Solutions

- Utilization of a risk management framework
- Lessons learned from other hazardous industries
- Incorporate insights from systems theoretic approaches

Courtesy: Dilbert.com

Insights & Conclusions

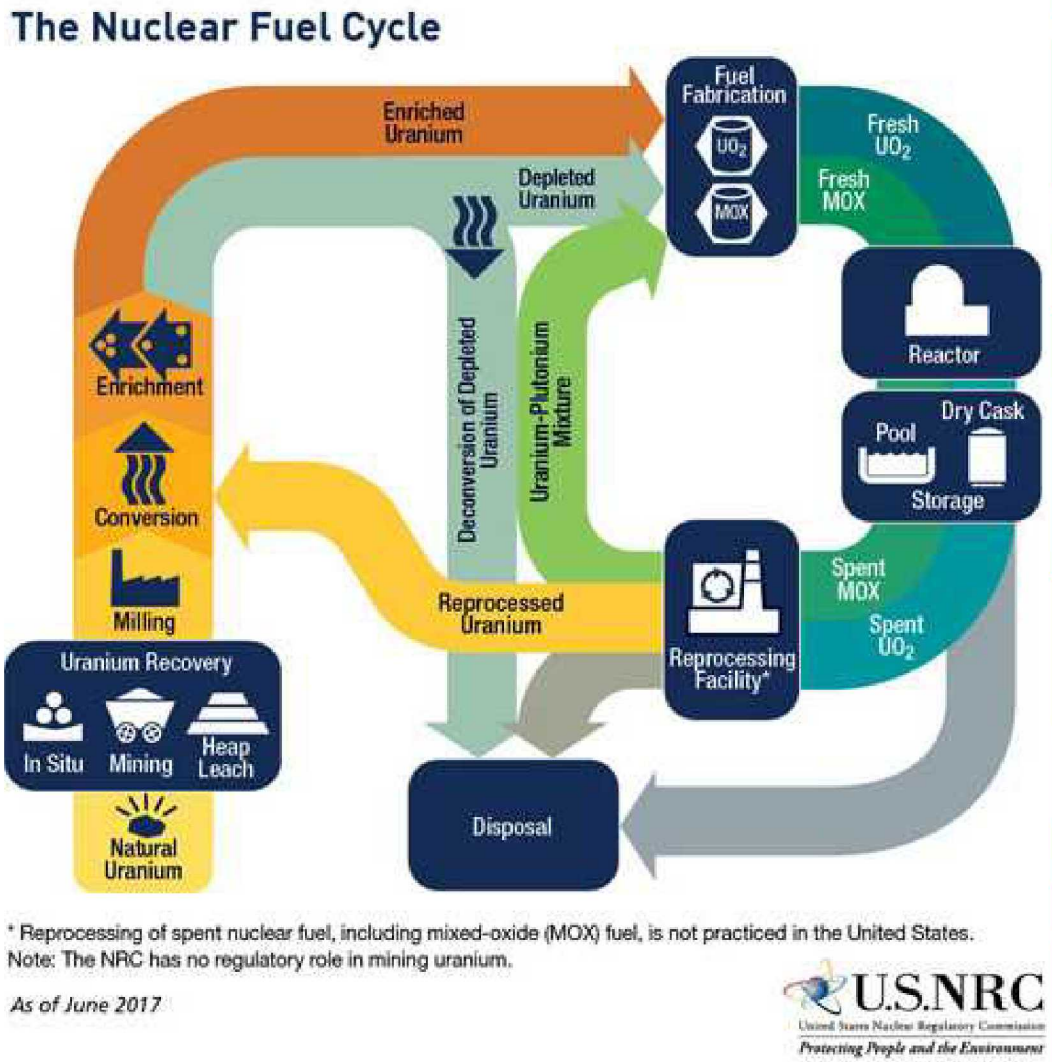
- Risk as the interaction of previously stove-piped areas of emphasis
- Risk management from ISO-31000 + systems-theoretic concepts
- Control micro-level risks to manage macro-level risks

Problem: Risk in the Nuclear Fuel Cycle (NFC)

Nuclear Fuel Cycle (NFC)
- Progression from creation to disposal
- Different *types* of fissionable materials
- Fuel to support energy production

Risk(s) in/to the NFC *can* include:
- Radiological hazards
- Safe operations of nuclear materials
- Secure control of nuclear materials
- Accountability for *civilian* uses
- Multinational NFCs

Risk(s) for the NFC are:
- Dynamic/Evolutionary
- Multi-faceted
- Complex



Courtesy: U.S. Nuclear Regulatory Commission

Problem: Increasing Risk Complexity in NFC

Photo of a mock SNF cask being moved from a container ship to heavy haul truck as part of a multi-modal, multi-jurisdictional international transportation route. Copyright: Sandia National Laboratories.

Two important notes regarding ***risk*** and the ***NFC***:

- Some degree of risk is inevitable
- Risks occur when they prevent desired NFC activities
- Traditional approaches rely separately on
  - Safety
  - Security
  - Safeguards

Safety, security & safeguards challenges to the NFC are growing & evolving

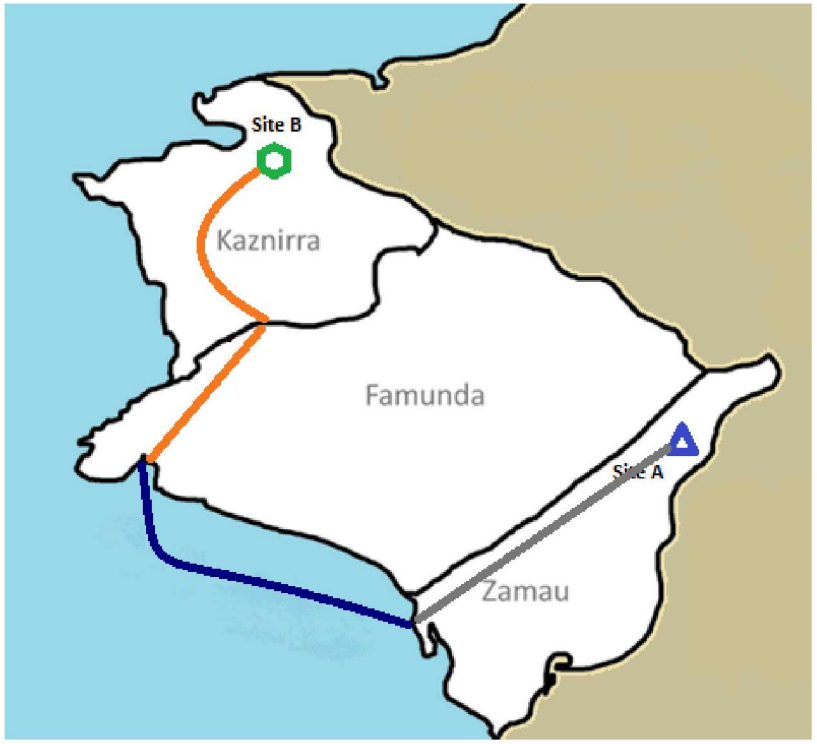
- Asymmetries in nuclear energy program capabilities
- Today's dynamic environment
- Emerging (aka., Disruptive) technologies

This represents an increasing **complexity** in the **risk** associated with NFC activities

Problem: Challenges to Risk Management in NFC

Example: The international transportation of spent nuclear fuel (SNF) faces ***more complex risks*** from a growing & evolving operational environment [Sandia/LDRD]

- Overlaps and possible gaps in risk mitigation responsibilities
- Conflicting objectives
- Increased number of transfers
  - Between transportation modes
  - Across geopolitical/maritime borders



Risk = ***anything*** that prevents physical movement of SNF

- From origin to destination
- Without disruption to selected/approved routes, timelines & operations

A New Approach: Risk Management Lessons Learned

Piper Alpha Platform Explosion
- Management system in place focusing on maintenance processes, not risk
- Did not have continual improvement process implemented
- System degenerated into informal processes
- 167 killed

BP Texas City Refinery
- Implemented management system lacked top down policies and leadership commitment
- Procedures were not well defined or enforced
- 15 killed

Deep Horizon Oil Spill
- Two systems completely independent of each other
- Stove piping caused systems gaps to be undiscovered
- Massive environmental impact

Photo of explosion on Piper Alpha, stock press photo

Loss of Nuclear Material from University
- Facility had implemented policies regarding security of materials
- Professor became complacent regarding the policies and left material unsecured
- Loss of 1.4 g of 90% enriched Uranium-235

A New Approach: Application of Risk Management

Risk management [Hubbard] includes

- Identifying, evaluating, and prioritizing risks
- Coordinated/economical efforts to minimize/control the probability/impact of events

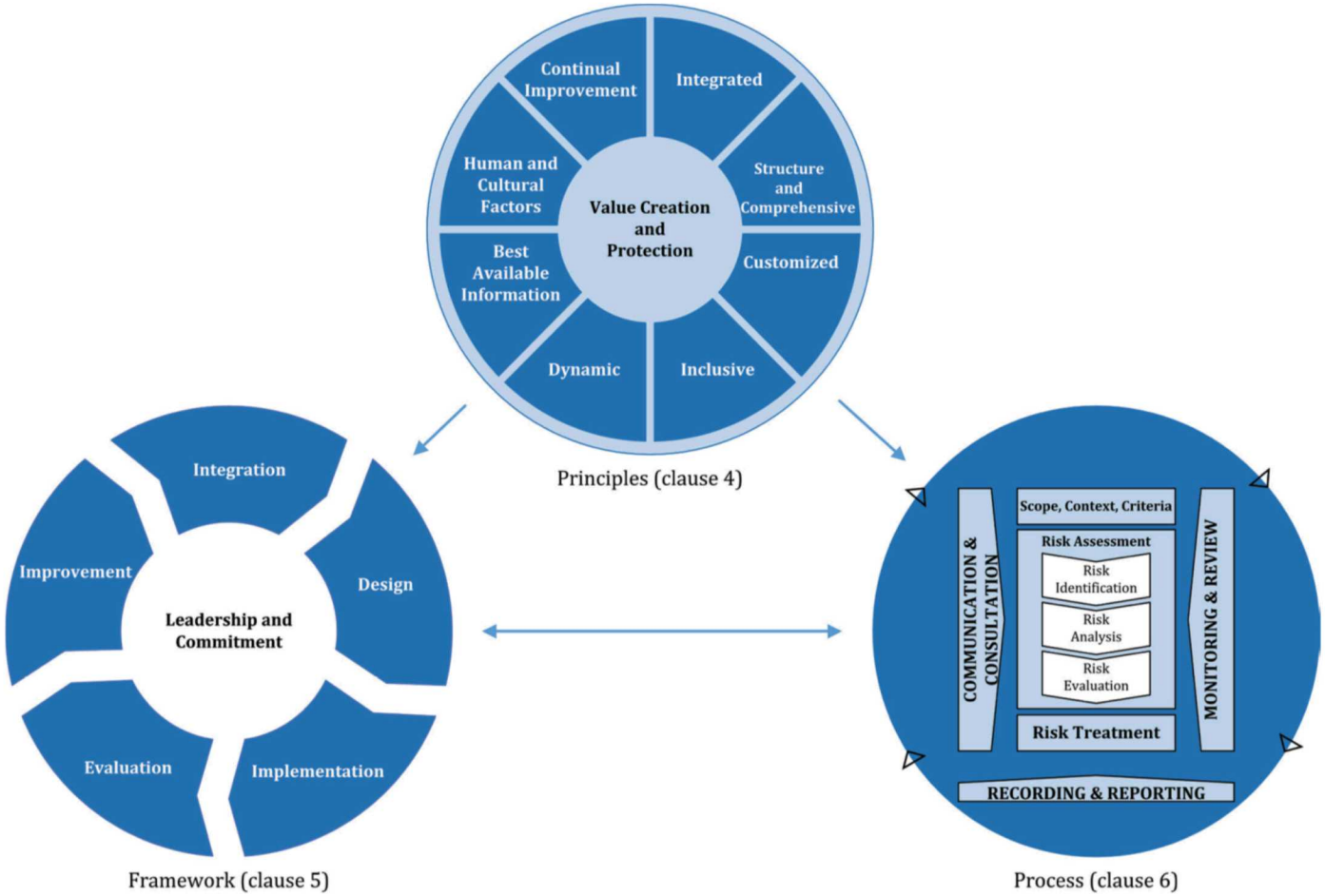
Chemical industries that implement risk management systems (to include Process Safety) have shown a ***reduction in issues*** and a ***increase in worker trust*** [OSHA]

Biological/chemical facilities integrating safety and security into a single risk management have demonstrated ***more effective risk reduction*** [OPCW, WHO]

- Better communication
- Increased risk management culture
- More effective use of limited resources

A New Approach: ISO-31000

ISO-31000—***Risk Management-Guidelines***—provides one such example



A New Approach: Systems-Theoretic Concepts (from LDRD)

Nuclear Fuel Cycle risks can be described in terms of:

- ***Organized complexity*** (e.g., "many, but not infinite" # of components)
- ***Dynamics*** (e.g. ordered systems migrate toward greater disorder)
- ***Interdependence*** (e.g., interactions affect behaviors)
- ***Hierarchy*** (e.g., relationships between levels of complexity)
- ***Emergence*** (e.g., irreducibility of certain system behaviors)

These ***concepts help describe these challenges*** to NFC risk management

A New Approach: "Complex Risk" (from LDRD)

From this perspective, "risk" & "risk management" → ***systems-level behaviors***

Mitigations (e.g., safety, security, & safeguards of SNF) → ***emergent system properties***

Complex risk includes the ***pressures*** & ***dynamics*** that prevent completion of desired objectives

- Accounting for social, political & technical contexts
- Addresses interdependencies observed between safety, security, & safeguards
- Includes technological reliability, procedural completeness, & patterns of human behavior

Helps to overcome tradition of "***stove-piping***" in NFC risk management

Calls for a structured process character & assess commonalities across NFC risks

A New Approach: ISO-31000 + Systems-Theoretic Concepts

NFC Risk Management		**ISO-31000**
Objective = *Protect public, environment while using nuclear materials*	→	Goal = *Value creation and protection for organizations*
Challenges to NFC Risk ◦ *Evolutionary* ◦ *Multi-faceted*	→	8 Principles ◦ *Dynamic* ◦ *Structured & Comprehensive*
"Complex Risk" ◦ *Interdependence*	→	5 Framework Steps ◦ *Integration*
Systems-theoretic concepts	→	"Iterative Process"

A New Approach: ISO 31000 + International SNF Transportation

Principles:

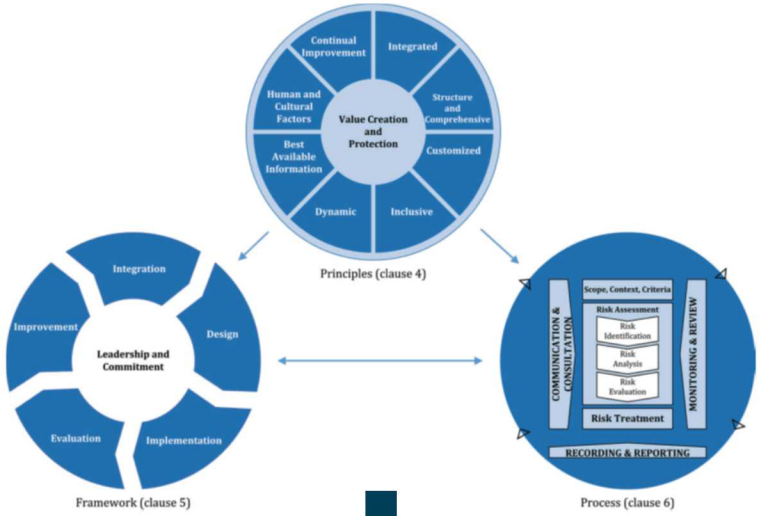
- ***Integrated*** → interdependencies between safety, security, & safeguards
- ***Inclusive*** → Increased awareness of risk management by all stakeholders in SNF transportation
- ***Best Available Information*** → Transparency on policies and issues

Framework:

- ***Design*** → Clear oversight and roles and responsibilities
- ***Implementation*** → Management commitment by all stakeholders
- ***Evaluation*** → Coordinated record-keeping & communications

Process:

- ***Scope/Context*** → Coordinated risks definition/metrics
- ***Risk Assessment*** → Evaluated jointly by all stakeholders
- ***Risk Treatment*** → Integrated risk mitigation measures implemented
- ***Monitoring/Review*** → Continued improvement efforts



Insights & Conclusions

Understanding risk in the NFC as the ***interaction*** of technical components and social dynamics among security, safety, and safeguards areas of emphasis

Reframe risk management as a trade space among desired—and highly interdependent—characteristics of NFC activities

- Lessons from risk management in hazardous industries
- Leverage ISO-31000
- Incorporate concepts of hierarchy, emergence, and control theoretic relationships

Shift risk management in the NFC to ***controlling*** sources of risk (at the micro-level) to improve ***managing*** risk observed in system behaviors (at the macro-level)