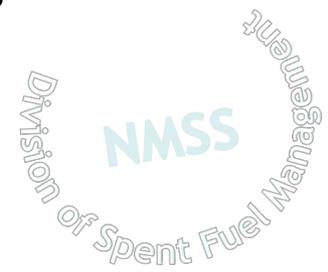


Inter-Agency Workshop on Defense-in-Depth

Dennis R. Damon
NRC Office of Nuclear Material Safety & Safeguards
August 26,27, 2015



Defense-in-Depth for Nuclear Materials

- NRC Office of Nuclear Material Safety & Safeguards
 - 5 program divisions covering at least 70 different types of nuclear facilities or uses of nuclear material that are NOT nuclear reactors
 - Regulates safety, security, and environmental impacts
 - Requirements, methods, and meaning of “defense-in-depth” vary among types of facilities, specific designs, and technical communities (e.g. chemical safety vs. nuclear criticality safety)

Some Types Of NRC-Regulated Nuclear Material Applications

- Nuclear medical devices and isotopes
- Nuclear gauges (is your coke can full?)
- Soil Moisture density gauges
- Gamma radiography cameras
- Sterilization irradiators
- Uranium enrichment for nuclear fuel
- Nuclear reactor fuel fabrication: naval and power
- Spent nuclear fuel storage (not onsite pools)

Some Types of NRC-Regulated Nuclear Material Applications

- Spent nuclear fuel transport packages
- Radioactive material transport packages
- High level radioactive waste disposal
- Low level radioactive waste disposal
- Decommissioning

Nuclear Material Safety

- This presentation primarily covers health and safety, not security or environmental
- Health and Safety: includes protection from routine radiation exposures and from accidents
- Hazards addressed: ionizing radiation, radioactive materials, radiation from nuclear criticality accidents, chemical effects associated with nuclear materials, indirect effects on nuclear material by fires, etc., natural phenomena hazards, external hazards (aircraft crashes into facility), long term behavior

Defense-in-Depth: Meaning

- Meaning 1: multiplicity of defenses, avoidance of over-reliance on any one defense (NRC use)
- Meaning 2: defense using depth and attrition (military use) – usually also uses multiple lines of defense, but need not

NRC Definition in SECY-98-144

- Defense-in-depth is an element of the NRC's Safety Philosophy that employs successive compensatory measures to prevent accidents or mitigate damage if a malfunction or accident occurs at a nuclear facility.
- The defense-in-depth philosophy ensures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of a nuclear facility.

Different Meanings in Different NRC Contexts

- Meaning 1a: multiplicity of independent defenses
- Meaning 1a(1): multiple barriers
- Meaning 1b: defenses beyond a first set of assumed defenses. The first set of defenses are not referred to as defenses in depth. Used in fuel cycle safety and probabilistic risk assessment
- Each fits the NRC definition
- But beware of the differences in meaning

Defense-in-Depth: Nuclear Material Examples

- Double contingency principle of nuclear criticality accident prevention:
 - “Double contingency means a process design that incorporates sufficient factors of safety to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible.”
- Double process piping for toxic materials

Defense-in-Depth: Nuclear Material Examples

- Required use of two different types of radiation dose rate meters, one with automatic alarm
- Nuclear fuel transportation:
 - 1) avoid transport accidents;
 - 2) containment package required to remain watertight after design basis accidents = crashes, drops, and fires;
 - 2) even if flooded with water nuclear criticality will not occur due to design.

Adequacy of Defense-in-Depth

- Some regulations require some kind of defense-in-depth, but not specific design features
- Other regulations require specific design features for defense-in-depth
- Some regulations have performance requirements that, in most circumstances, will require multiple independent controls to satisfy
- In these cases “adequacy” may have been determined for the situations to which the regulation applies by NRC guidance

Adequacy of Defense-in-Depth

- NUREG-1860 has a discussion of general principles of defense-in-depth that is generic for nuclear reactors
- There is no comparable generic defense-in-depth guidance for non-reactor nuclear applications
- AIChE Center for Chemical Process Safety has guidance on adequacy of “Layers of Protection” that depends on frequency of challenges and magnitude of consequences

Adequacy of Defense-in-Depth

- Quantitative risk sensitivity and uncertainty analysis have been used to evaluate quantitative degree of impact of single elements on meeting a quantitative risk criterion
- These sensitivities are a quantitative test of DID adequacy
- Some specific NRC DID criteria are quantitative
- No generic NRC quantitative risk DID guidance
- Risk sensitivity/uncertainty metrics are widely used for prioritization however.