Preclosure Safety Analysis Event Sequence Analysis Summary

Presented to:
Nuclear Waste Technical Review Board

Presented by:
Michael V. Frank
L&NS – Preclosure Safety Analysis
Bechtel SAIC Company, LLC

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Outline

- Preclosure Safety Analysis (PCSA) Uses Probabilistic Risk Assessment (PRA) Technology
- What is the appropriate level of aggregation for an event sequence in the PCSA?
- How are important to safety (ITS) items identified?
- How is the nuclear safety design basis (NSDB) established?

PCSA Uses Probabilistic Risk Assessment Technology

- **Risk Triplet based**
  - **"What can go wrong?"**
    - **A set of scenarios or event sequences**
  - **"How likely is it?"**
    - **Compilation and processing of available evidence including historical records of events, probabilistic engineering analysis (e.g. seismic fragility, structural reliability), judgment of experts**
    - **Via event sequence diagrams (or the equivalent event trees) and fault trees, the probability of unlikely scenarios may be estimated**
    - **Uncertainties in event probabilities essential to the processing**
  - **"What are the consequences?"**
    - **Defined by decision-maker (e.g. project manager or regulatory agency)**
    - **PCSA Consequences: Dose to off-site public, dose to on-site workers and public, criticality**
- **Risk Triplet is excellent "operational" definition in that it is a synopsis of how the PCSA is performed**

Concept of an Event Sequence

A perturbation from normal operation that might, with other events, lead to a consequence

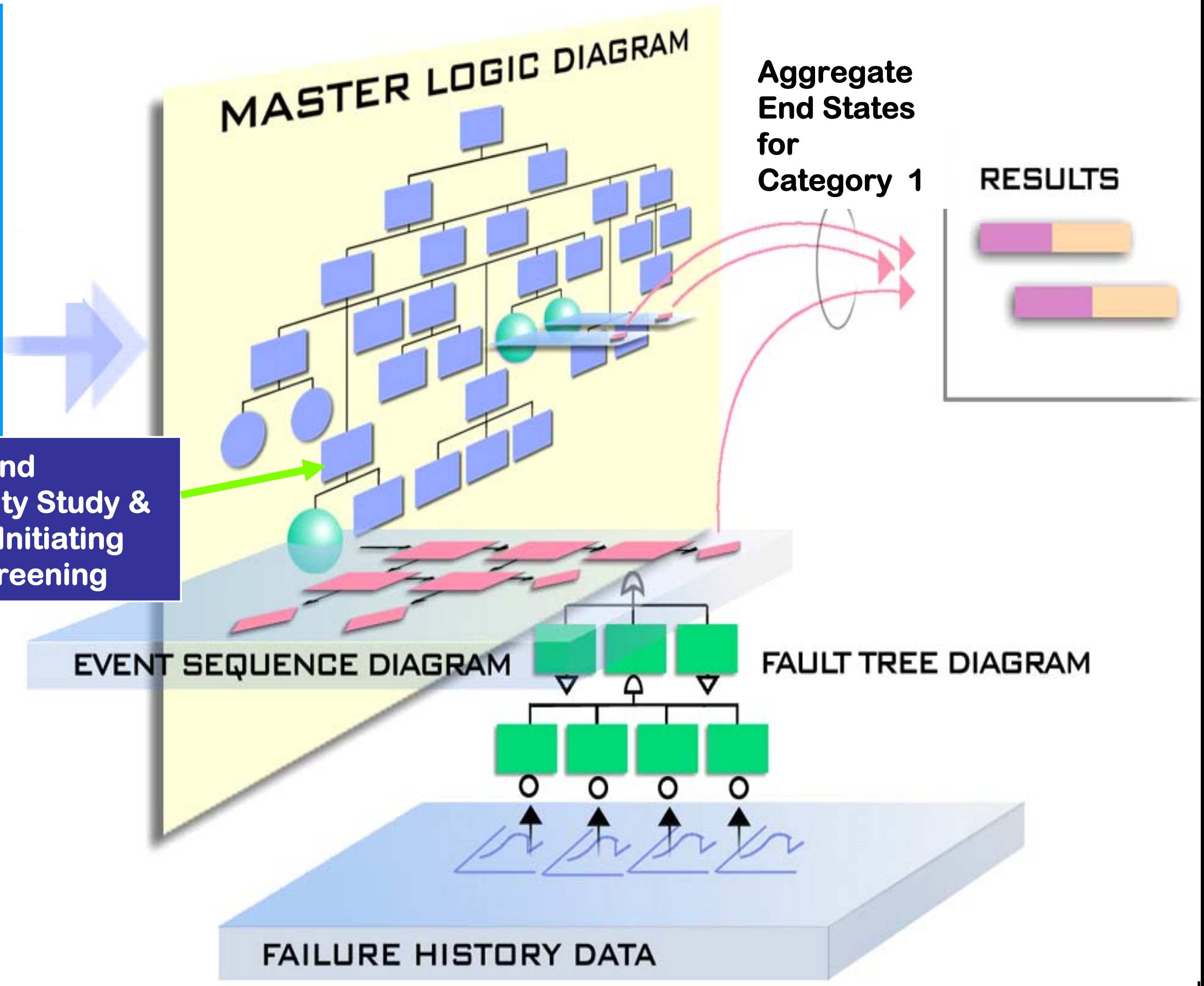
Represents system, facility, human response to the initiating event

Consequence of interest: Radionuclide release, direct exposure, criticality

Event Sequence Development Summary

DETAILED FACILITY, SYSTEMS, STRUCTURES, COMPONENTS, AND OPERATION KNOWLEDGE

Hazard and Operability Study & External Initiating Event Screening



What is the Appropriate Level of Aggregation for an Event Sequence for the PCSA?

NRC Regulation for YMP PCSA

- **Application under 10 CFR 63 leads to differences from nuclear power plant applications as follows:**
  - **Category 1 (>= 1 over preclosure period) event sequences for onsite dose are to be aggregated as a yearly dose and compared to 10CFR20 limits; Category 1 event sequences for offsite dose at site boundary are aggregated as a yearly dose and compared to 15 millirem/year**
  - **Category 2 (< 1 but >= 1E-04 over preclosure period) event sequences categorized one at a time on the basis of probability only, not on the basis of risk (e.g. cumulative expected consequence of all scenarios)**
  - **Offsite dose for each Category 2 event sequence is to be calculated and compared to the dose performance goal at the site boundary (5 rem); Onsite dose not required to be calculated**
  - **There shall be no criticality for Category 1 and 2 event sequences**
  - **No consequence analysis needed if Beyond Category 2 (< 1E-04 over the 100 year preclosure period)**

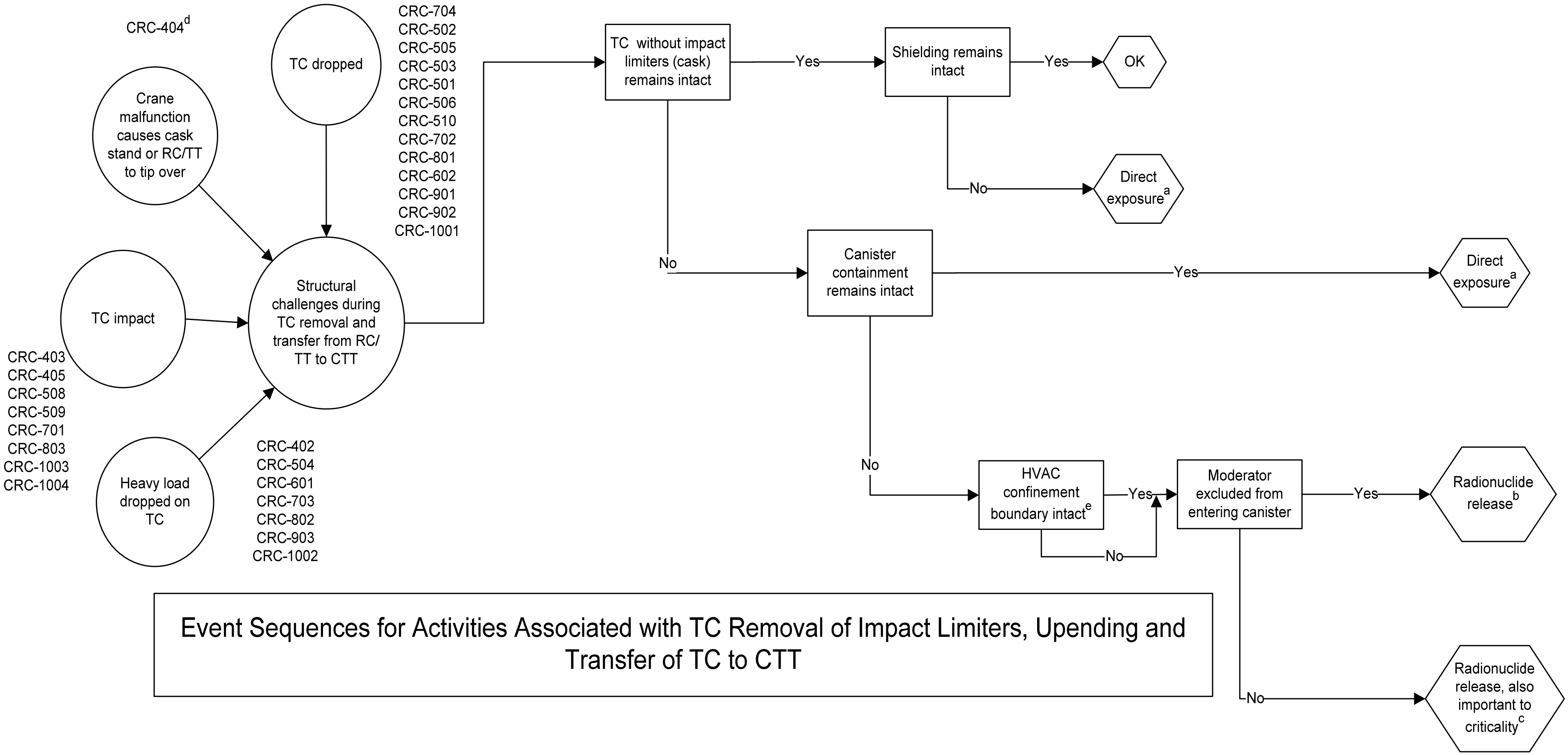
Dilemma Caused by 10 CFR 63

- The level of aggregation (or level of resolution) of events represented in an event sequence is fundamental to categorization
  - Higher levels of aggregation means higher frequency of each event sequence
    - Example: Impact and breach of canister
      - » Should a single event sequence include all drops of all types of canisters from all possible sources in all facilities? Or should there be more resolution with respect to sources, facilities, and canister types
- Important for risk management
  - Reliability requirements of ITS structures, systems, and components (SSCs) derived from event sequences

Accuracy

- **Criterion for level of aggregation is representational accuracy**
  - **For example separation into different event sequences warranted because of variations of:**
    - **Facility configuration and operations (leading to different challenges, e.g. lift heights, number of lifts, residence time)**
    - **Equipment (although some equipment is similar across facilities, the complement of equipment is different for each facility)**
    - **Waste forms and containers (variation in robustness over different casks and canisters and variation in source terms because of different fuel/form of fuel)**
- ***Event sequences should be disaggregated to represent different waste processing functions*, different waste forms/containers, and different facilities***
  - **** E.g. receipt, preparation, transfer, welding, load-out, transport, and emplacement***

Concept of Event Sequence Diagram (For illustration only – not actual result)



Event Sequences for Activities Associated with TC Removal of Impact Limiters, Upending and Transfer of TC to CTT

Important to Safety Definition

- *Important to safety,* with reference to structures, systems, and components, means those engineered features of the geologic repository operations area whose function is:
  1. To provide reasonable assurance that high-level waste can be received, handled, packaged, stored, emplaced, and retrieved without exceeding the requirements of § 63.111(b)(1) for Category 1 event sequences
  2. To prevent or mitigate Category 2 event sequences that could result in radiological exposures exceeding the values specified at § 63.111(b)(2) to any individual located on or beyond any point on the boundary of the site

What SSCs are ITS?

- **An SSC is classified as ITS if it appears in an event sequence, and at least one of the following criteria apply:**
  - **The SSC is relied upon to reduce the frequency* of an event sequence from one category to the next**
    - **Apply reliability improvement measures to HVAC and cranes to reduce coincident breach and loss of HVAC to beyond Category 2**

* Categorization is based on the mean frequency of the underlying probability distribution of each event sequence

What SSCs are ITS?
(Continued)

- **The SSC is relied upon to reduce the aggregated dose of Category 1 event sequences by reducing the event sequence frequency**
  - **Interlocks on shield doors, slide gates, TEV door to reduce potential direct worker exposure frequencies**
  - **The SSC is relied upon to perform a dose mitigation or criticality prevention function**
    - Canisters and casks are ITS because they serve a containment function
    - HVAC is ITS because it serves a confinement function
    - Staging Racks in the WHF pool are ITS because they are required to ensure adequate separation for subcriticality

Nuclear Safety Design Bases

- **Safety functions are identified for each SSC classified as ITS**
- **NSDBs are then specified for each ITS SSC to ensure that the ITS SSCs perform their safety functions**

Example NSDB Types

- NSDBs are of the following types:
  - Mean frequency of ITS SSC failure on demand
  - Preventive maintenance and/or inspection interval relied upon in the fault tree analysis of an ITS SSC
  - Mean unavailability of ITS SSC over time period
  - Mean frequency of earthquake-induced event sequence

BACKUP

Preparation Area

- **Collisions**
  - Tug vehicle with walls or shield door
  - Crane yoke with canister
  - Cask transfer trolley with walls or shield door
- **Drop from Crane**
  - During tilt up
  - During movement to cask transfer trolley

Canister Transfer Cell

- **Crane drop**
  - Into transportation cask
  - Into waste package or aging overpack
  - Within shield bell
  - Through bell lower gate to second floor
- **Collision**
  - Within shield bell
  - Canister transfer machine (CTM) to CTM
  - Trolley with wall or shield door

Canister Transfer Cell

- Shear event
  - Concurrent horizontal and vertical motion
    - CTM or trolleys
- Drop w/o waste package
- Lid drop
- Angled drops

Waste Package Closure Area

- **Rapid tilt down**
  - **Before closure**
  - **After closure**
- **Lid drop**
- **Trolley collision or derailment**

Load Out Area

- **Rapid tilt down**
- **Transport and emplacement vehicle (TEV) related**
  - **Interrupted or failed transfer to TEV**
  - **Inadvertent TEV door open**
  - **TEV derails**
  - **TEV collision with doors**
- **Inadvertent shield door opening**

General

- Loss of HVAC thermal transient
- Worker inadvertently enters transfer cell, waste package closure area or load out area