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Systems Analysis for Evaluation of Safeguards Effectiveness

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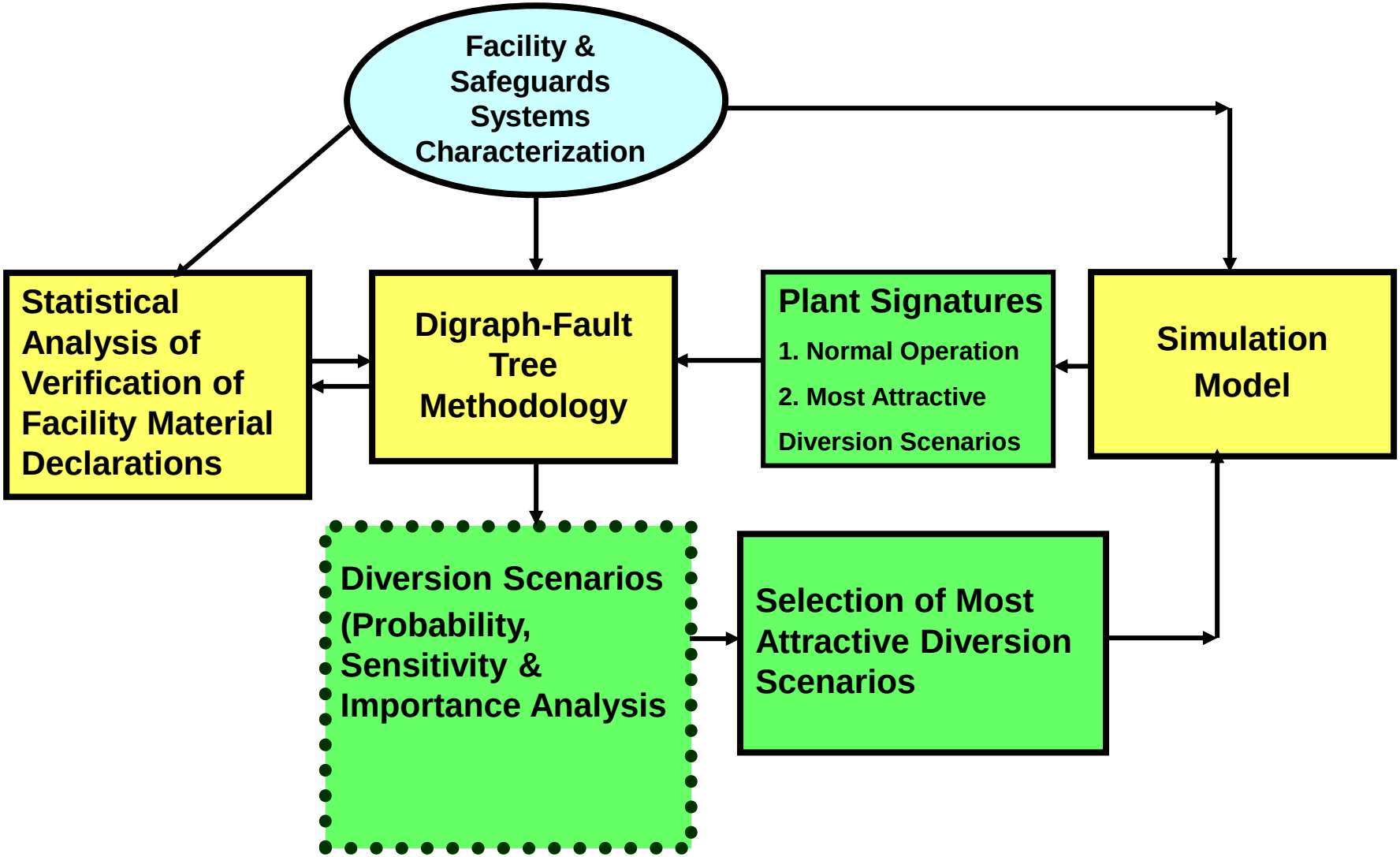
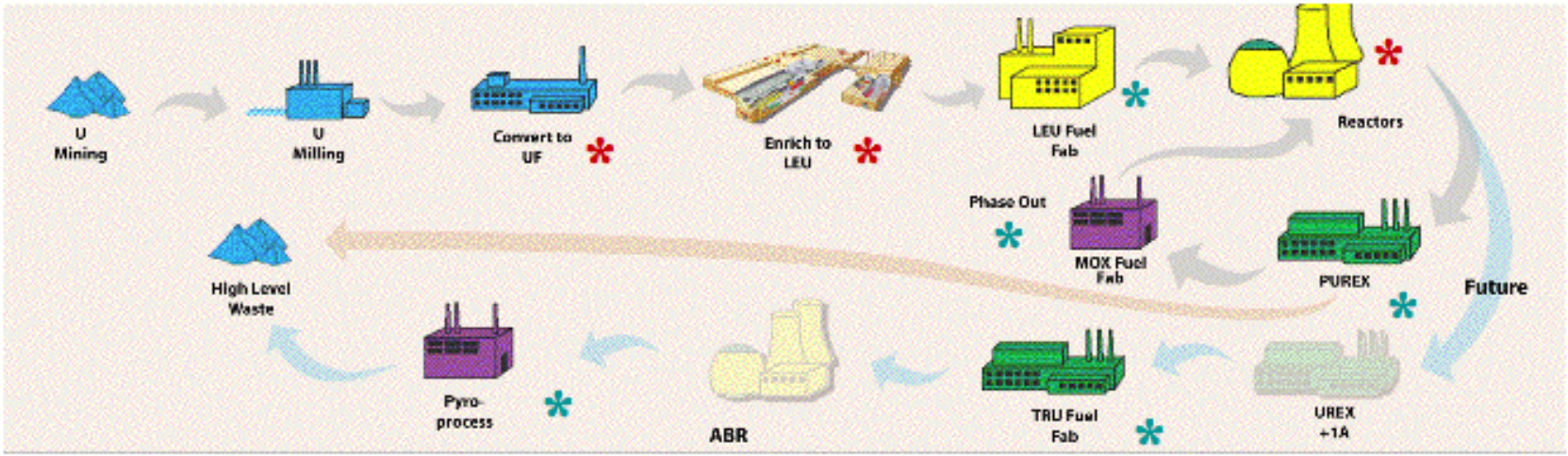
Overview

- ***LLNL Integrated Safeguards System Analysis Tool*** **- (LISSAT) performs systems analysis for evaluation of safeguards effectiveness**
  - **Safeguardability and cost-effective assessments**
  - **For existing facilities/operations and current safeguards strategies or future technologies ("design-in safeguards")**
  - **Will present examples for conversion and enrichment facilities**

LLNL Integrated Safeguards System Analysis Tool (LISSAT)



Current & potential use of LISSAT for Nuclear Fuel Cycle assessments



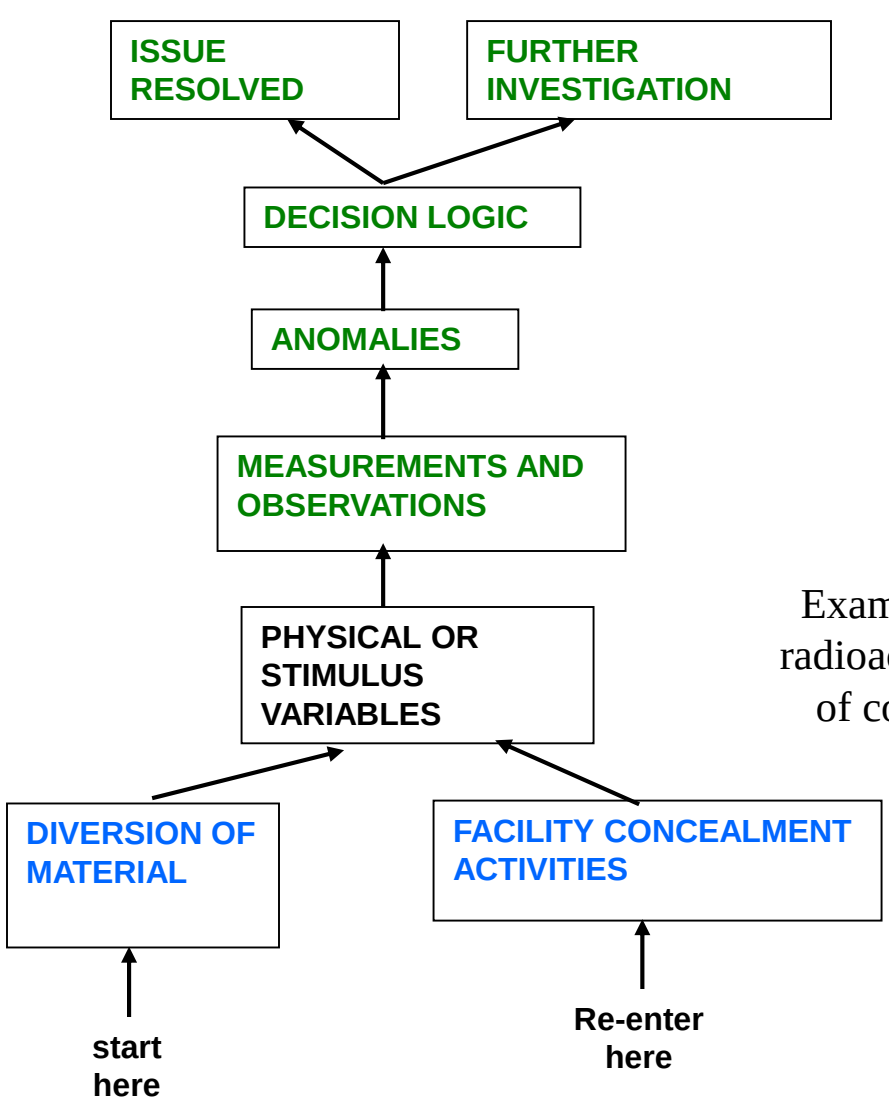
* Current use of LISSAT * Potential use of LISSAT → Material Tracking Potential use of LISSAT

LISSAT Components

Directed Graph (Digraph)/fault tree analysis

- **Provides a *structured systematic approach to incorporate all root causes for each diversion scenario* including operator misdeclarations**
- **Help *quantify the change in the probability of detection of diversion* due to the introduction or use of:**
  - **Material accounting, surveillance cameras, detectors…**
  - **New safeguards measures/tools**
  - **New technology**
  - **Changes in plant designs**
- **Help analyze cost-effectiveness of options**

Flow of Information Regarding Detection Paths in the Digraph



IAEA ACTIONS

Examples, flow, concentration, mass, radioactive emissions, number and type of containers, facility configuration

Clandestine actions in facility

Statistical Evaluation Provides Basic Event Probabilities

- For detecting falsifications of parts of the material balance, we use IAEA statistical goals and methods
- For finding physical activities of diversion, we use overlap of randomly timed inspections and short-time diversion activities
- For equipment performance and human error, we use high-tech industry experience
- Deliberate actions have a probability of 1.0

Comparison of Effectiveness

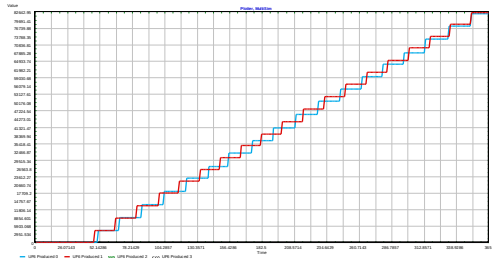
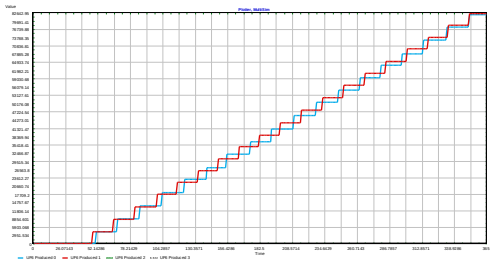
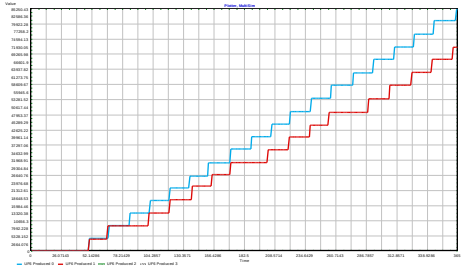
Safeguards strategies for different diversion scenarios

Example Diversion Scenario	Current Safeguards	Added Safeguards Measures
Without any Safeguards measures	With current Safeguards practice	With surveillance cameras, detectors…
1.0	Probability of diversion	Reduction in probability of diversion

Simulation

- **Help *identify plant signatures* (normal versus abnormal) that might assist IAEA inspectors as indicators of diversion**
- **Help *identify the ideal location* of detectors, measurement sensors, surveillance cameras…**
- **Use Extend (v.6) to develop a simulation model for selected facility**
  - **Extend is a graphical, interactive, general-purpose simulation program for both discrete event and continuous modeling**
  - **Allow manipulation of circumstances**
  - **Illuminates signatures to identify anomalies**
  - **These anomalies can be fed-back into the fault tree analysis**

Identify the Ideal Placement of Detectors and Monitors

	Material Measurement Points		
	Measurement point 1	**Measurement point 2**	**Ideal location Measurement point 3**
Diversion Scenario	 **No difference in signatures**	 **No difference in signatures**	 **Difference in signatures**

Generic Conversion Plant

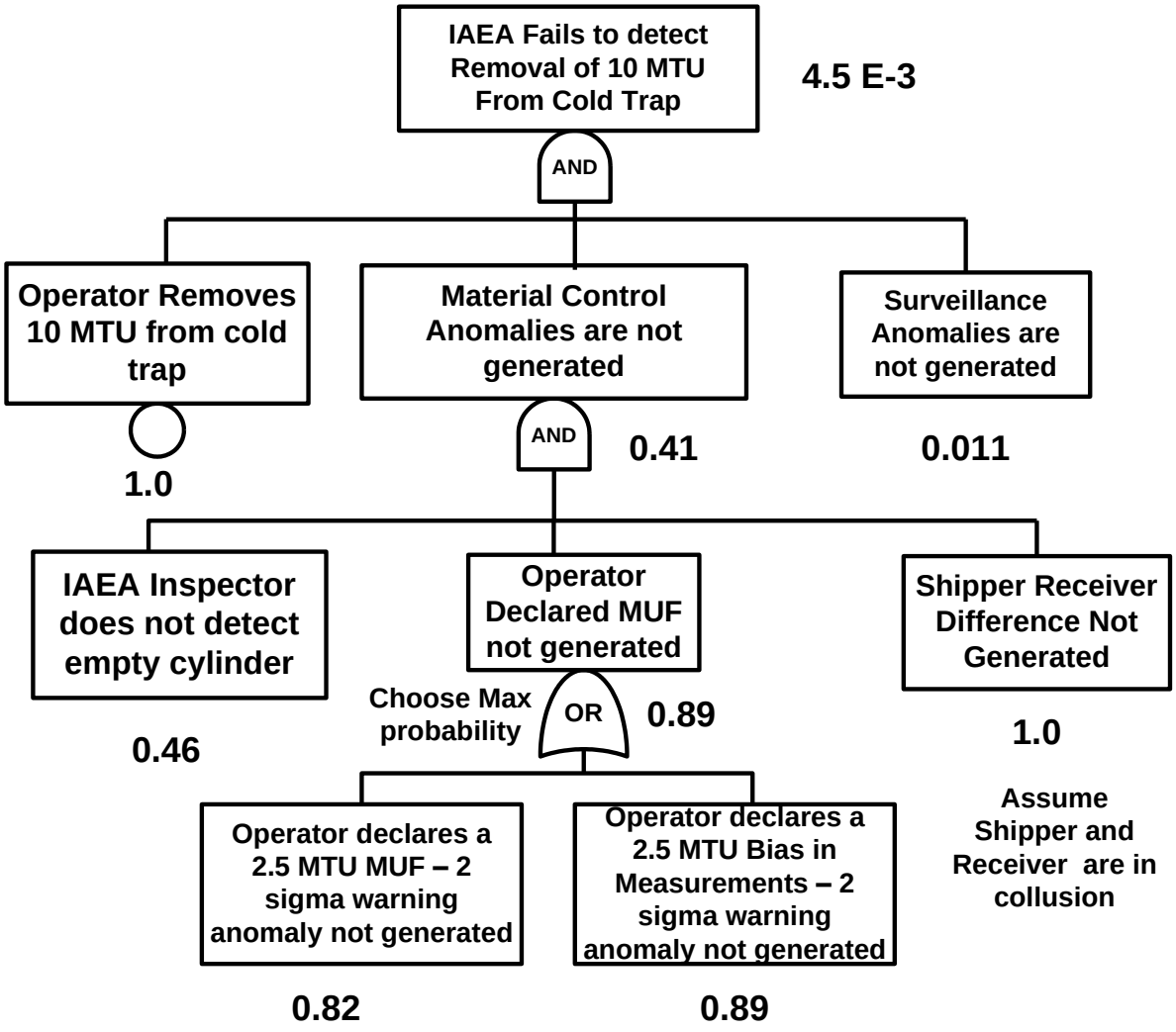
- **Model Assumptions**
  - **Small sized plant**
  - **100 MTU per year**
  - **Modeled for 1 calendar year**
  - **Measurement points at input and output only plus addition of surveillance**

- **Diversion Path Analysis**
  - **Removal of 10 MTU as UF_6 from the cold trap in three batches, *and***
  - **Material balance falsification using one misdeclared product cylinder of UF_6 (7.5 MTU) uranium**

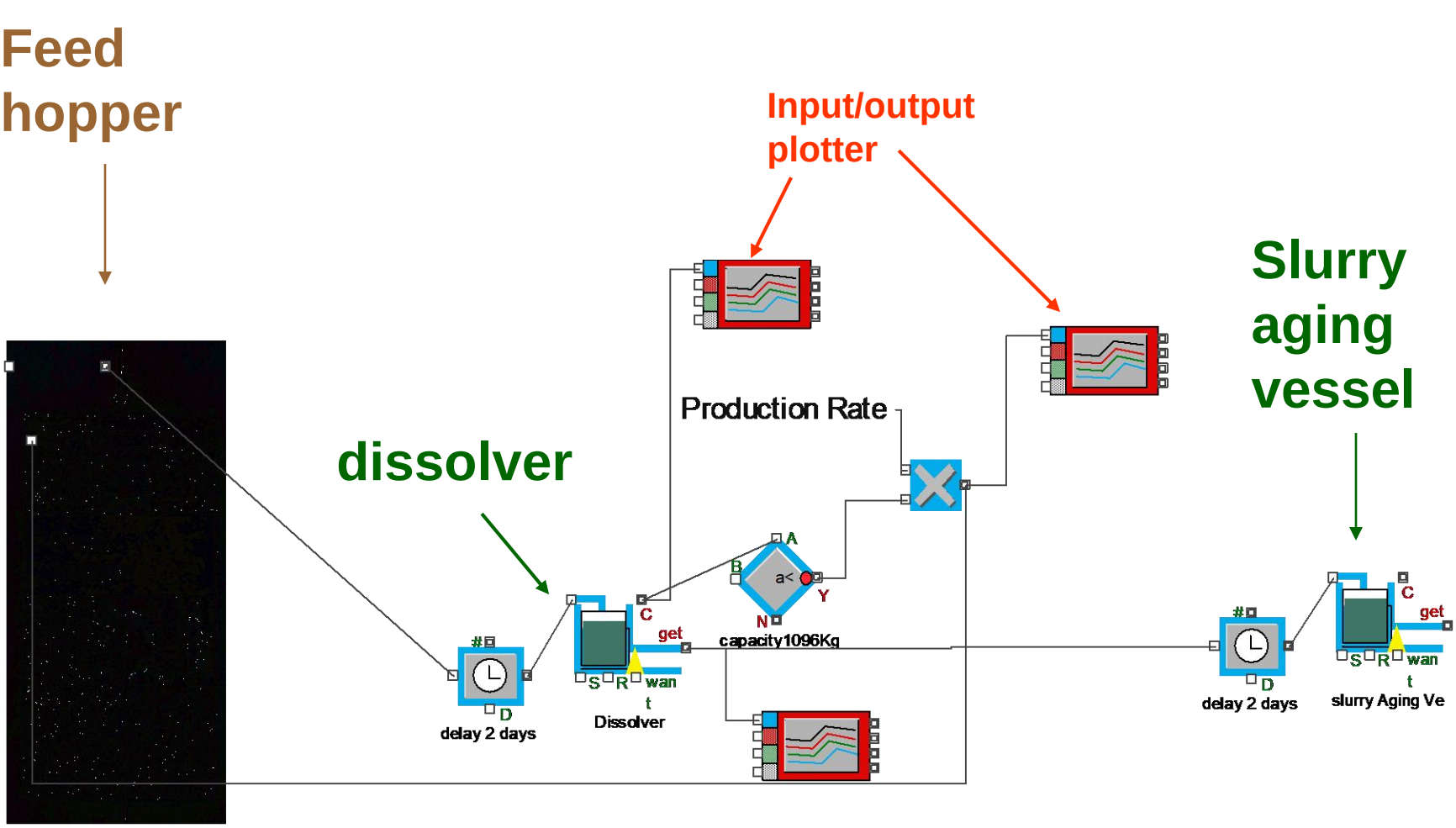
Quantify the Change in the Probability of Diversion as a Result of Introducing Measures

		Material accounting Current Safeguards practice		Surveillance camera at cold trap Added Safeguards measure		Use both Safeguards measures
	No Safeguards measures	With Material Accounting	Decrease in probability of diversion	With Surveillance	Decrease In probability of diversion	
Diversion at the Cold Trap	1.0	0.41	factor of 2.5	0.011	factor of 90	0.0045

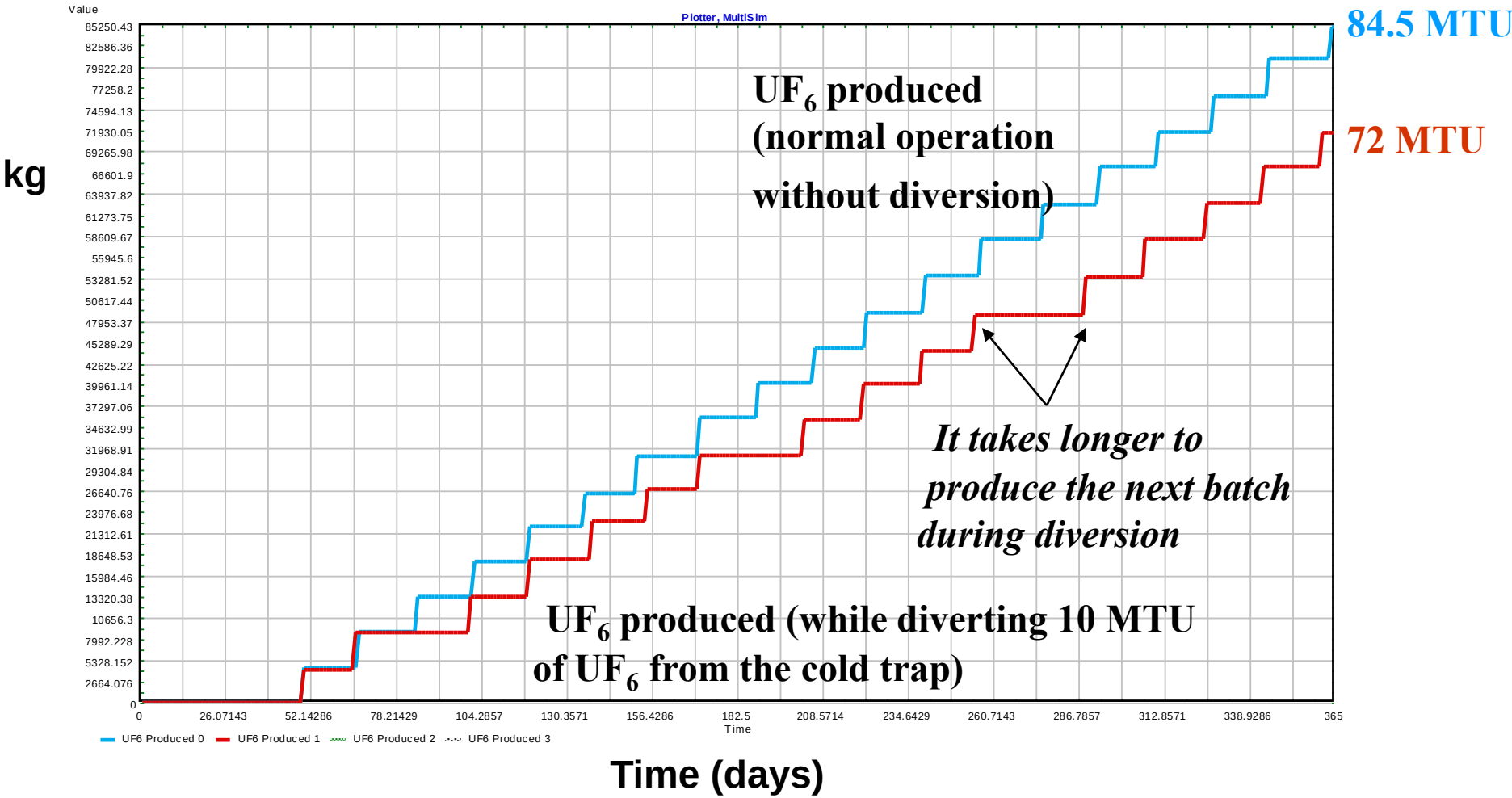
Top Level Fault Tree



Conversion Facility Feed Hopper Simulation Module in EXTEND



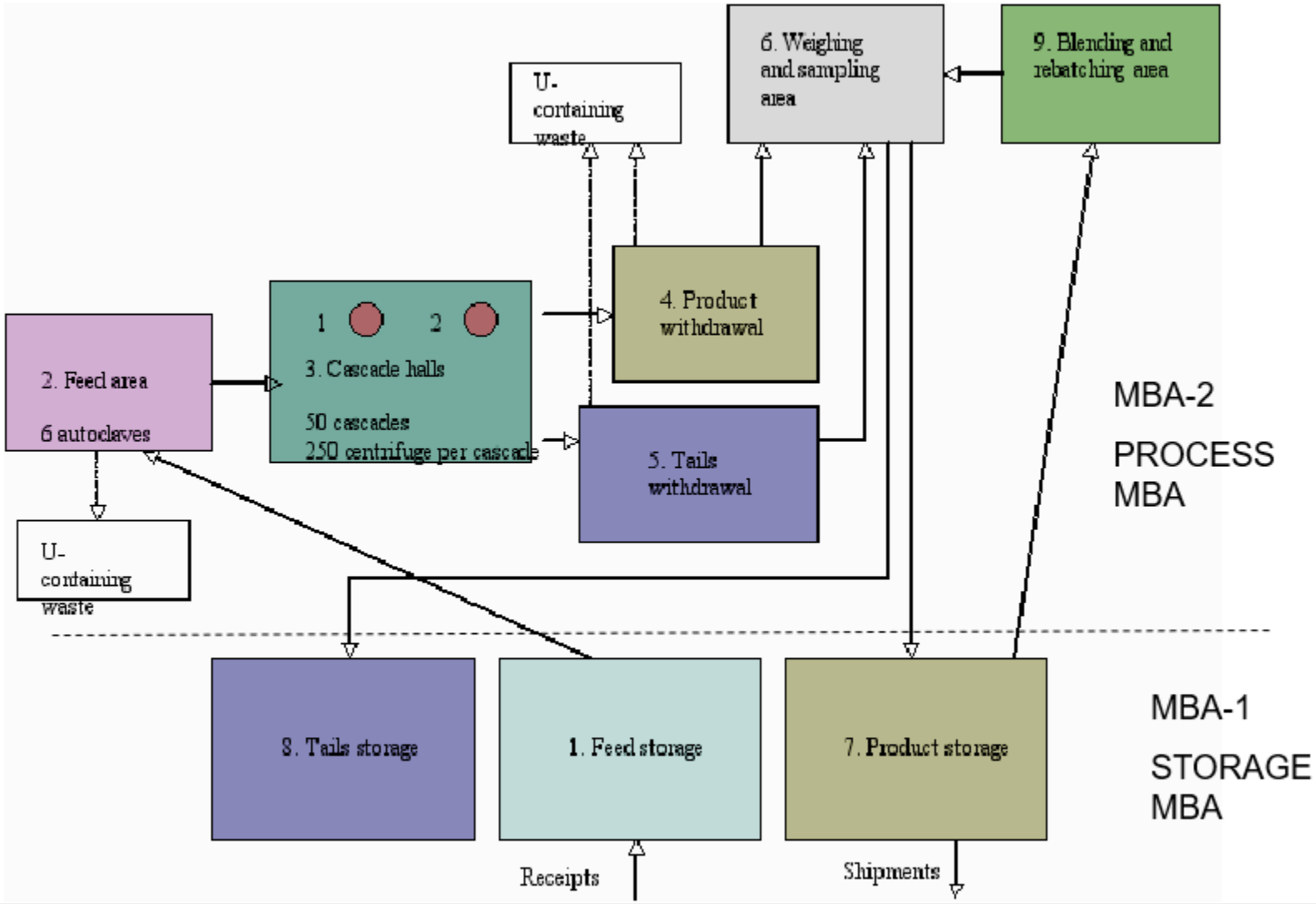
Simulation of Total Annual Production of UF_6



Generic Enrichment Facility
Model Assumptions

- URENCO Plant General Layout
- ORNL Input (capacity, flow rates)
- Medium sized generic enrichment plant
- 500 MTSWU per year
- There are 6 autoclaves
- Cylinders are shipped to autoclaves - one cylinder every 3 days
- One cylinder holds 7602 kg U
- Flow into cascade hall is 102.6 kg/hr
- There are 50 cascades
- There are 250 centrifuge per cascade

Generic Enrichment Facility



Diversion Scenarios Considered

- **Production and diversion of a significant quantity of highly enriched uranium (HEU)**
- **Diversion by skimming of a significant quantity of declared LEU product**
- **Production of LEU in excess of declared amounts by using undeclared feed.**
- **Excess LEU production scenario based on operator overstatement of the tails U-235 concentration**

Safeguards Strategy

Safeguards measures considered:

- **Fixed Monthly Inspections (FMI)**
- **Short Notice Random Inspections (SNRI)**
- **Limited Frequency Unannounced Access inside Cascade Hall (LFUA)**
- **Load Cells for container weights while emptying/filling**
- **Video Surveillance Feed, Product and Tails Station**
- **Continuous Enrichment Monitor on cascade product headers**

Scenario

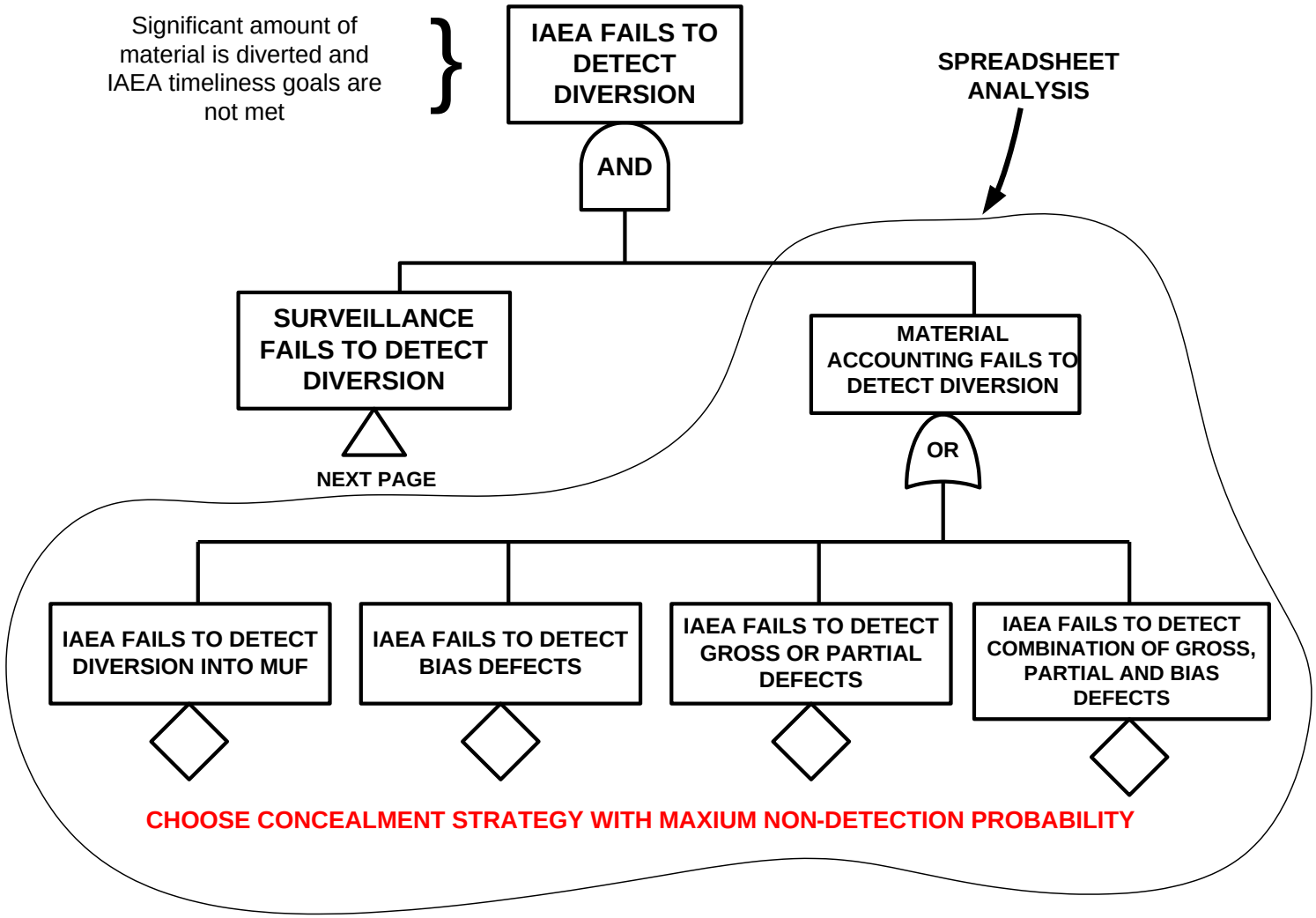
Diversion by skimming of a Significant Quantity of declared LEU product from two withdrawal points:

- **Normal (outside cascade hall) – product station**
- **Inside cascade hall – assume collection carts are use to remove product**

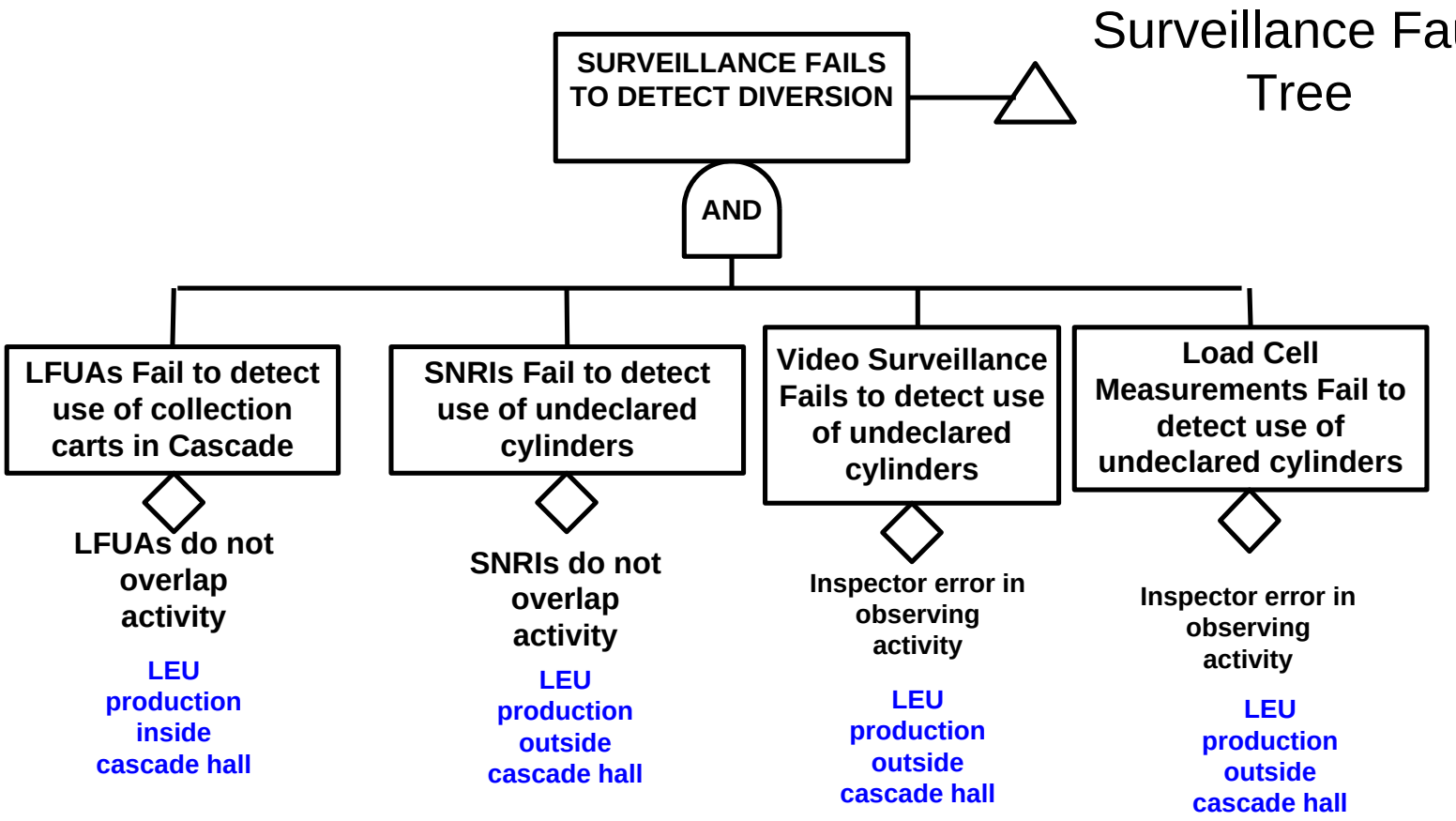
Simulation model assumed:

- **Gaseous impurities losses 0.3%**
- **Modeled for one calendar year**
- **Diversion of LEU product by skimming inside the cascade hall**

Generic Fault Tree Structure Used to Develop Diversion Scenario



Generic Fault Tree For Surveillance Failure



SNRI = Short Notice Random Inspections

Additional Safeguards Measures are Being Proposed for Effectiveness and Efficiency

- **Cascade header unattended monitors can reduce probability of undetected HEU production while allowing reduction in number of LFUA's**
- **Randomly timed inspections (SNRI's) in place of fixed monthly inspections can increase probability of observing item anamolies, and possibly reduce number of inspection trips per year.**
- **Video surveillance of feed product and withdrawal station can reduce probability of undetected undeclared feed.**

Potential Use and Application of LISSAT

- **To evaluate effectiveness of existing and enhanced safeguards tools/methods *- must carefully define the questions*, for example:**
  - **Placement of detectors**
  - **Optimize Safeguards strategy**
  - **Help direct future technology R&D requirements**
  - **“Design-in Safeguards” for future facilities**
- **Application for a broad range of facilities and processes**
  - **Current and advanced**
- **Evaluation of proliferation risk reduction**
- **Improved user interface will facilitate general application of tool**