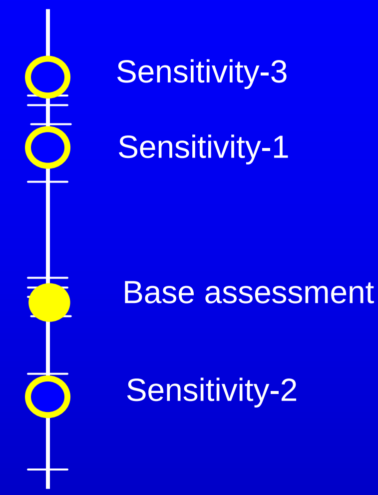
MODULE 10: **Treatment of Uncertainties**

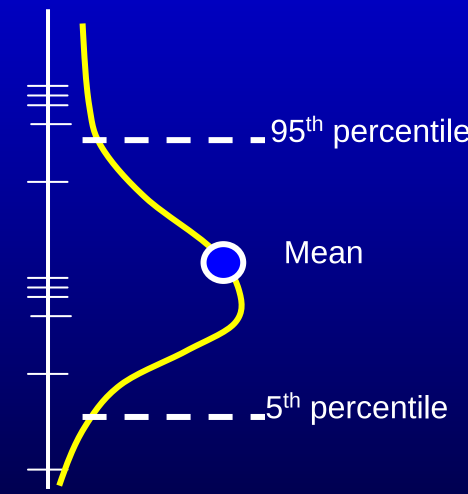
OUTLINE

- Uncertainty versus Sensitivity
- Types of Uncertainty
- Methods for addressing uncertainty in a Level 2 PSA

Uncertainty vs Sensitivity

- **Sensitivity & Uncertainty Analysis provide answers to different questions:**
  - *Sensitivity analysis*: **how would results change if different values were chosen for uncertain parameters?**
    - **Generates an different** *point estimate* **of risk measures**
  - *Uncertainty analysis*: **what level of confidence can be attributed to a risk measure?**
    - **Generates a probability** *density function* **for risk measures**

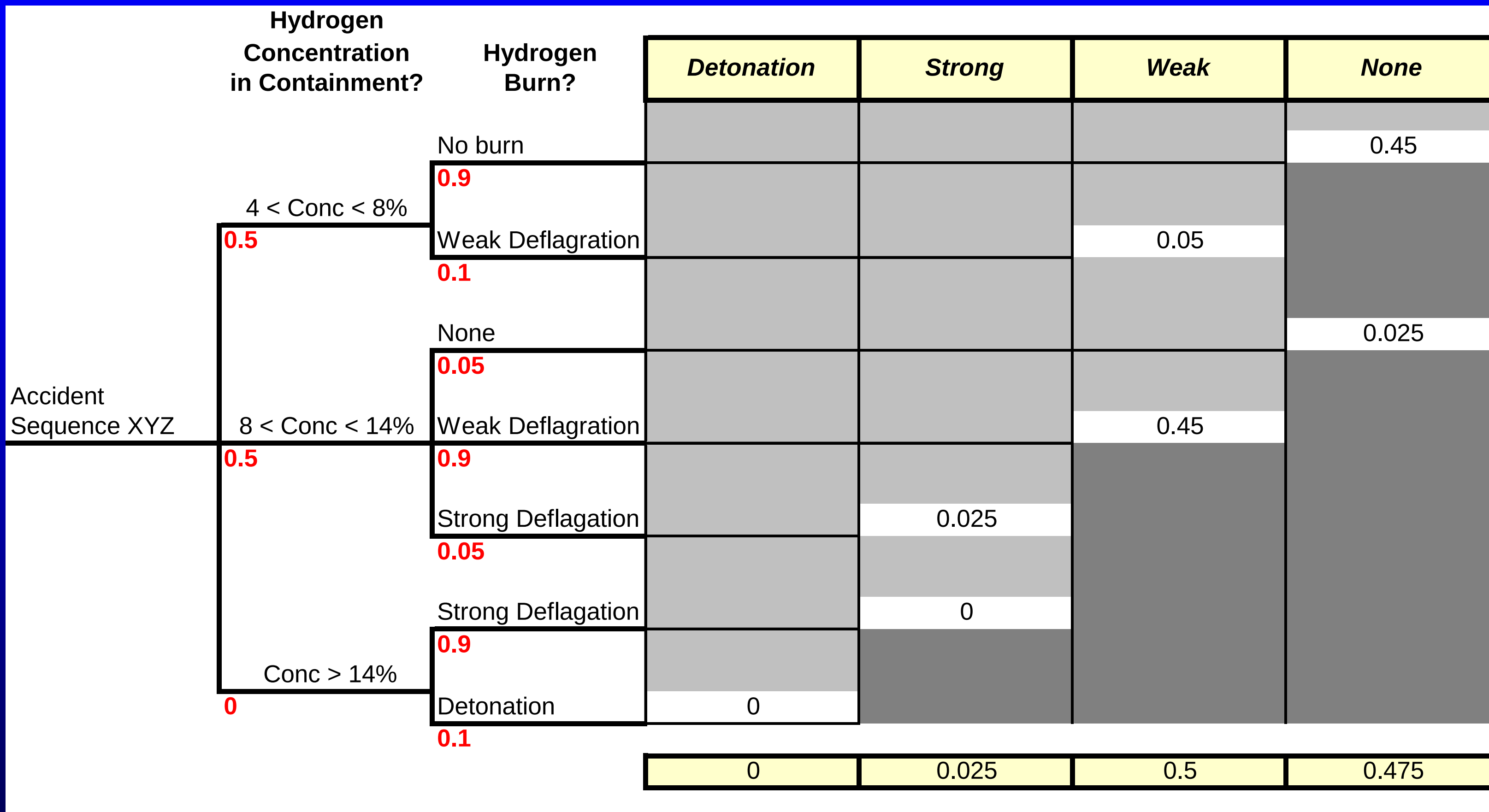




Uncertainty vs Sensitivity (2)

- Sensitivity studies are an important element of a Level 2 PSA.
  - Determine which parameters “control” accident progression and/or source terms.
  - Quantify the range of possible event outcomes, examples:
    - How range of containment pressure increments might accompany RPV lower head failure?
    - How much could the source term change if the containment failure pressure were 12 bar instead of 10 bar?
- Uncertainty analysis assigns probabilities to the spectrum of outcomes for individual events and combines them to evaluate their combined effect on plant response.

Sensitivity Analysis in Level 2 PSA (2)



Types of Uncertainty

- **Probabilities developed in a Level 2 PSA carry uncertainty from two sources –**
  - **Stochastic or random behavior (**aleatory **uncertainty)**
  - **Lack of adequate knowledge (**epistemic **or "state-of-knowledge" uncertainty)**
  - **Epistemic uncertainties can be reduced over time, as more data are collected from research. Aleatory uncertainty cannot be reduced by further study.**

Aleatory - examples

- Probability containment isolation valves fail to close on demand
- Probability a safety/relief valve sticks open after n-demands

Epistemic - examples

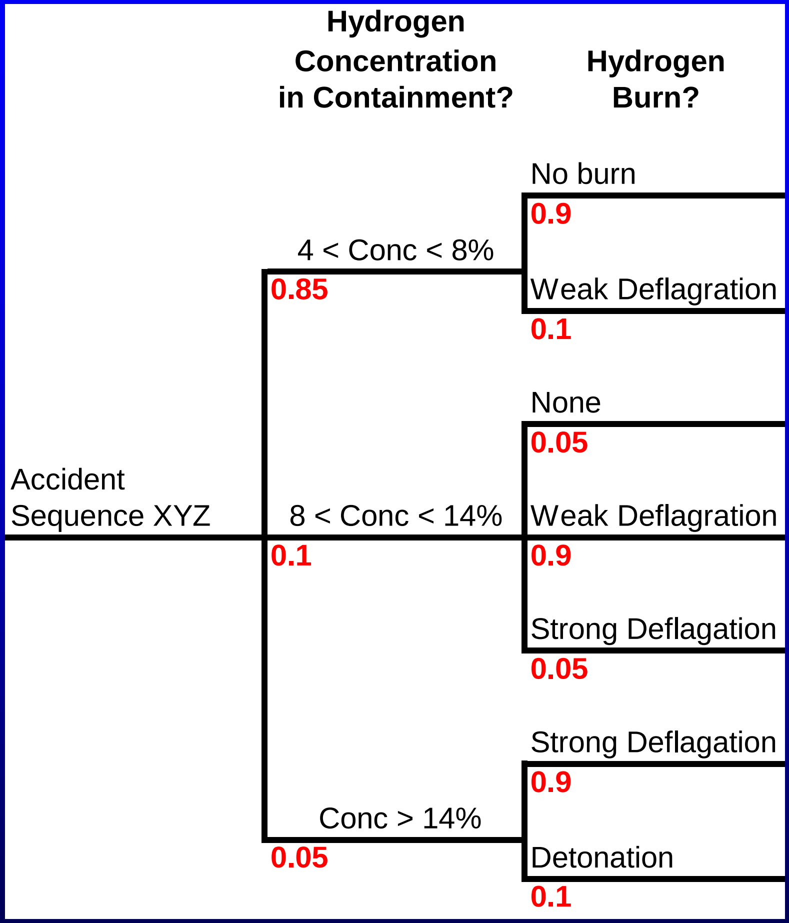
- Amount of hydrogen generated before RPV lower head failure
- Containment failure criteria
- Coolability of debris when submerged in water

Types of Uncertainty (2)

- Both types of uncertainty are treated probabilistically, although with different methods
  - Aleatory uncertainties: traditional data analysis
    - Calculation of event probabilities based on available data
  - Epistemic uncertainties: structured expert judgment
- Ideally, a Level 2 PSA model should separate the assessment of these two forms of uncertainty
  - A “bridge tree” addresses system issues (with aleatory uncertainty) not covered by Level 1 analysis
  - The CET addresses severe accident progression issues (with epistemic uncertainties)
  - Many studies blend the two together in a single analysis framework (i.e., no distinction between type of uncertainty)

Uncertainty Analysis in Level 2 PSA

- All Level 2 PSAs address uncertainties in severe accident behavior in the framework of the CET
  - Branches on the CET represent uncertain junctures in accident progression
  - Split fractions represent informed judgment about likely vs unlikely outcomes



Uncertainty Analysis in Level 2 PSA (2)

- A complete uncertainty analysis involves a more complex treatment of split fractions in the CET:
  - Split fractions (probability) not constants; replace fixed values with probability density functions
  - Propagation of uncertainty across the CET events via Monte Carlo sampling (or equivalent)
- Only one published Level 2 PSA applied this method
  - U.S. NRC: NUREG-1150 (1990)
  - Required specially-developed (non-standard) tools for propagating uncertainty distributions through an event tree structure (EVNTRE, LHS, and several other codes)
  - Although the method represents the current state-of-the-art in Level 2 PSA, it has not been generally adopted for general applications

Uncertainty Analysis - Summary

- A quantitative evaluation of the effects of major uncertainties is an important element of contemporary Level 2 PSA
  - Recommended in Regulatory Review Guidelines developed by IAEA [IAEA-TECDOC-1229]
- Detailed, systematic sensitivity studies are generally an acceptable surrogate for true uncertainty analysis
  - Identify parameters/issues that control results
  - Identify parameters that dominate overall uncertainty
  - Determine whether uncertainty in specific parameters is important (do they impact results?)