Uncertainties in Fire PRA

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Background

- All fires - approximately 0.3 per year per nuclear plant unit
- Fire CDF - approximately 1×10^{-5} per reactor year
- No core damage due to fire
- Wide range of fire events

Four Factor Formula

- **Fire CDF is computed using:**

$$CDF = \Sigma_i \lambda_i [SF]_i [P_{NS}]_i [CCDP]_i$$

i = Fire scenario i

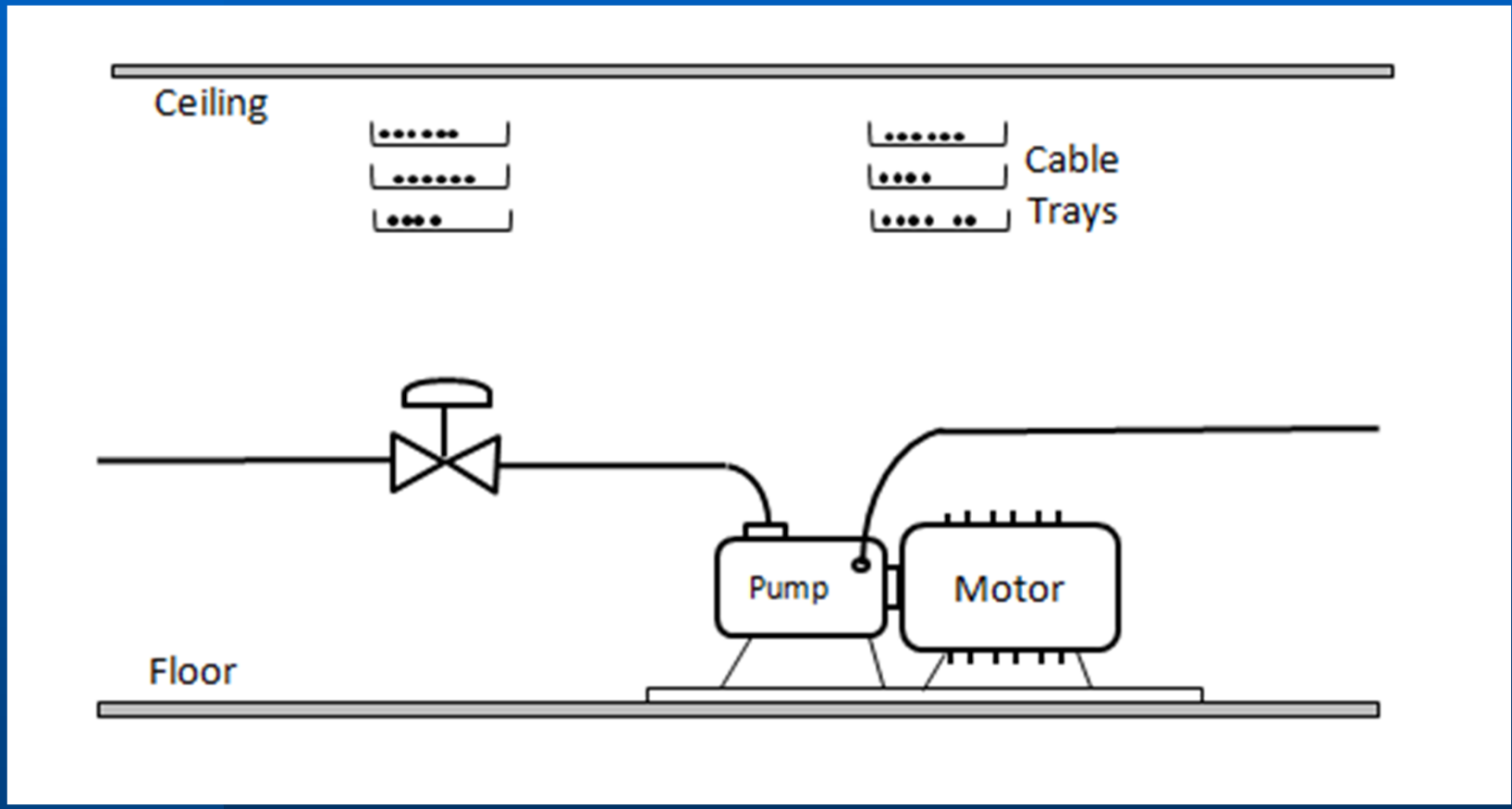
λ = Frequency of fire ignition

[SF] = severity factor

[PNS] = Probability of non-suppression

[CCDP] = Conditional Core Damage Probability give the fire scenario

Example

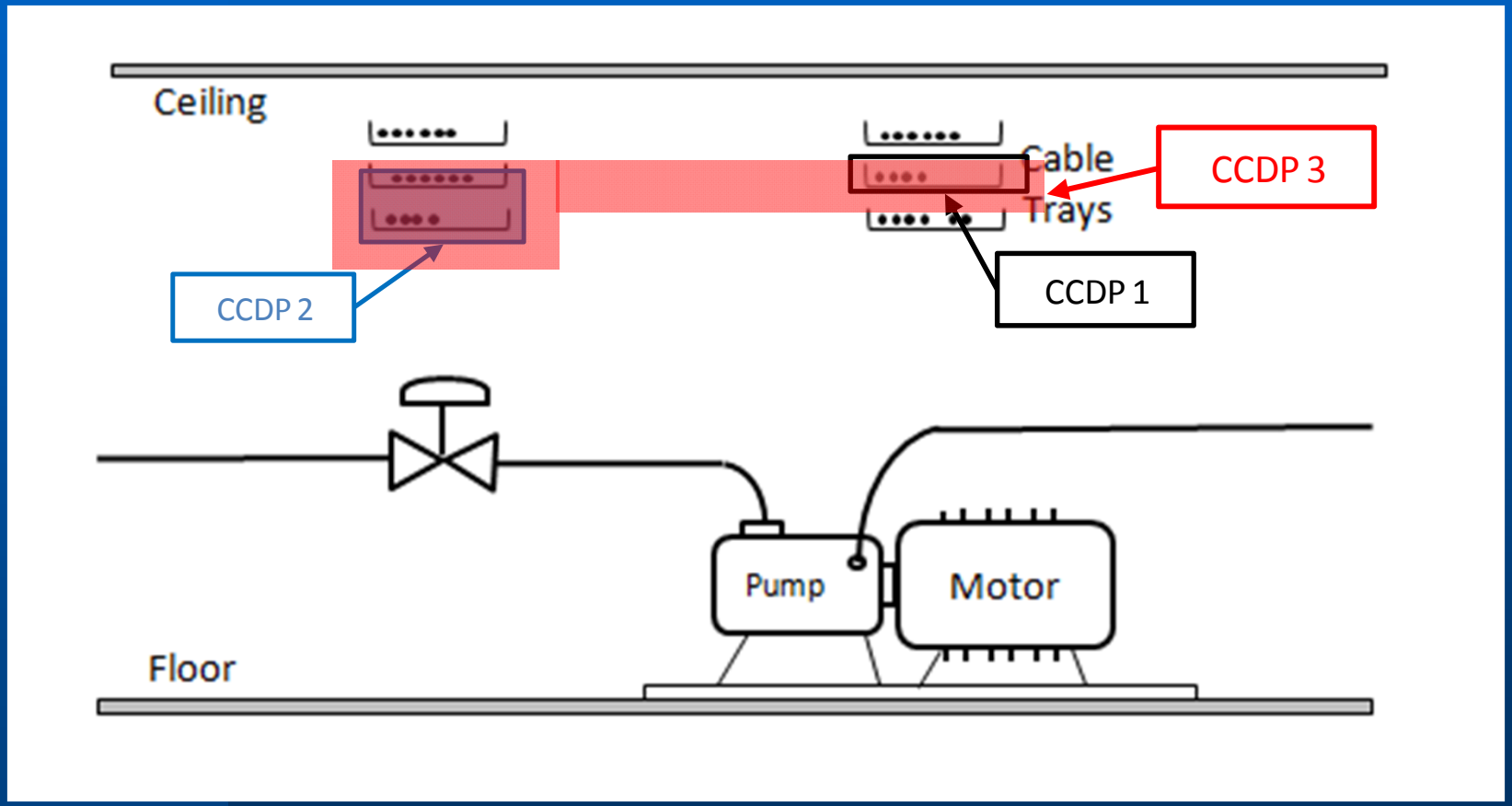


Fire Scenario in Fire PRA

- **A fire scenario can be defined in terms of the following elements:**
  1. **The target set**
  2. **Fire occurs at the ignition source** *(precisely defined)*
  3. **Fire suppression systems fail to control the fire before target damage** *(includes the fire brigade)*

Underlying the scenario is a well defined compartment with well defined fire protection features.

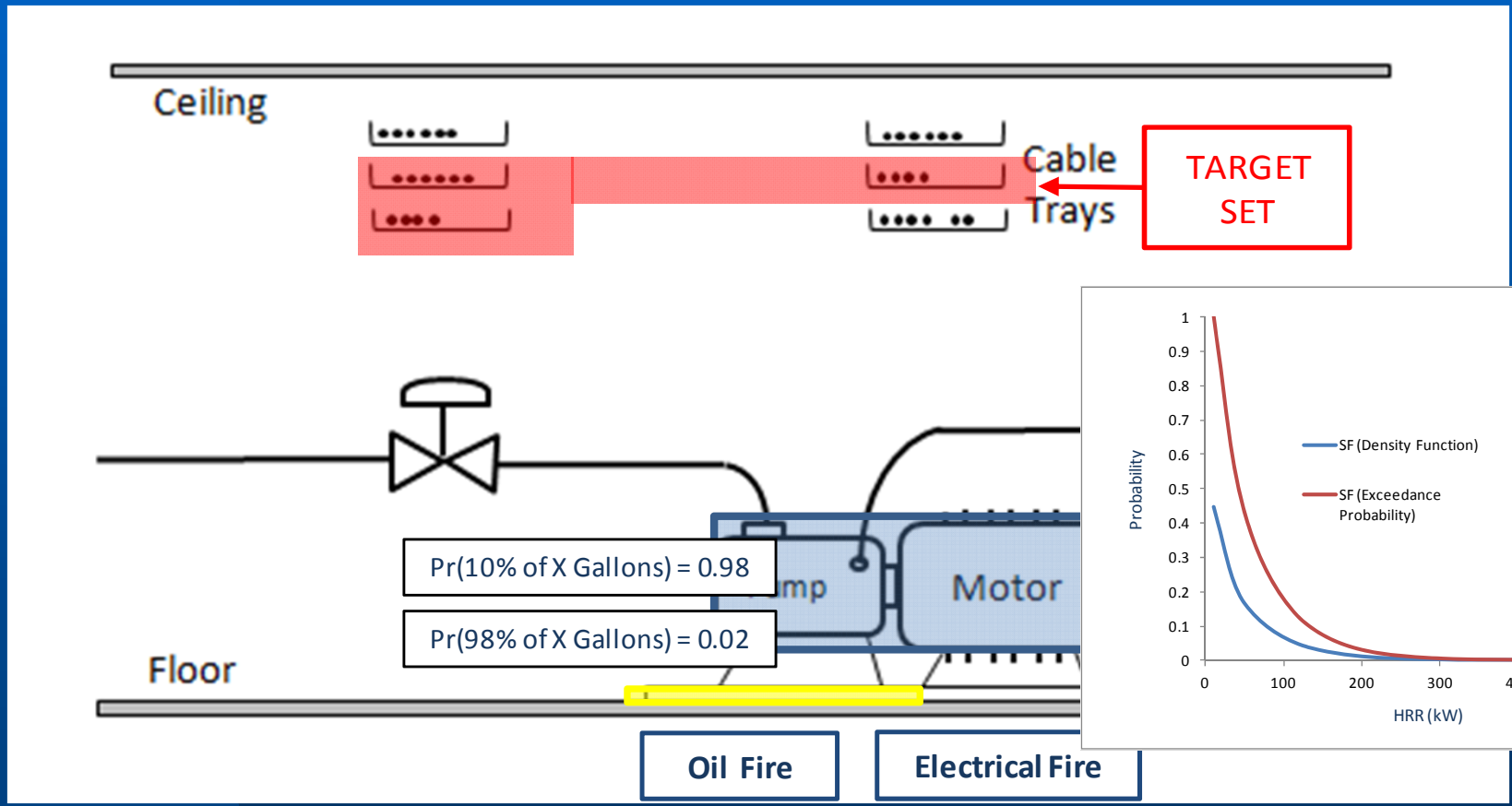
Target Set Definition



Uncertainties in CCDP

- **Circuits present in a cable** – *epistemic (could be significant)*
- **Failure modes of each circuit** – *aleatory (epistemic part not quantified)*
- **Selection of the target sets** – *epistemic (depends on analysts' skill and resources)*
- **Operator actions** – *aleatory (epistemic part affected by fire scenario)*

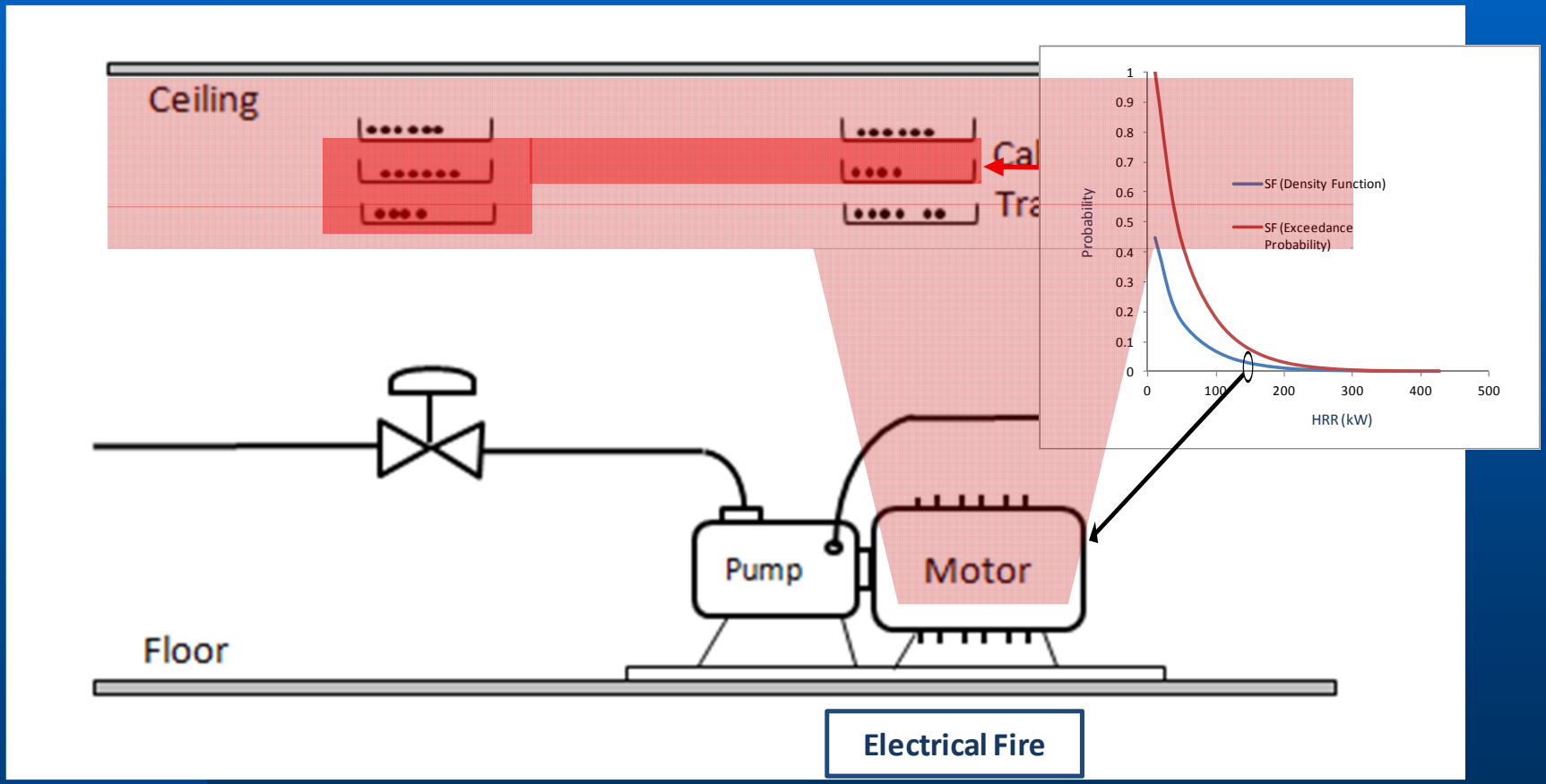
Ignition Source Definition



Uncertainties in Fire Frequency

- **Bin frequency** – *aleatory (epistemic part medium)*
- **Binning (e.g., pump size and type)** – *epistemic*
- **Split fraction for type of fire (e.g., electric vs. oil)** – *aleatory (epistemic part not quantified)*
- **Plant specific events** – *epistemic*

Fire Propagation Modeling



Uncertainties in Time to Damage

- **Input parameters:**
  - **Heat release rate –** *aleatory (epistemic part not quantified)*
  - **Damage threshold** – *epistemic (not quantified)*
- **Selected computational model –** *epistemic (V&V effort)*

Uncertainties in Probability of Non-Suppression

- **Fire detection system effectiveness** – *epistemic (not quantified)*
- **Fire suppression systems effectiveness** – *epistemic (not quantified)*
- **Fire detector reliability** – *aleatory (epistemic part not quantified)*
- **Automatic suppression systems reliability** – *aleatory (epistemic part not quantified)*
- **Fire brigade response** – *aleatory (epistemic part quantified – small)*

What is not modeled in detail

- Smoke impact on equipment
- Smoke impact on operator actions
- Use of alternate shutdown panels
- Fire brigade actions leading to additional failures
- An electrical short leading to fires elsewhere
- Operators' response to bad information
- Combination of external events (e.g., turbine blade ejection leading to fire and flooding)

Uncertainties in Fire PRA

- **Selecting target set – small**
- **Impact on operator actions – can be large**
- **Ignition frequency – medium**
- **Severity factor – large**
- **Time to damage – medium**
- **Prob. of non-suppression – small**

Uncertainty in Fire PRA

- **Quantify epistemic uncertainties of all aleatory uncertainties**
- **Identify and treat epistemic uncertainties correctly**