Applying Functional Safety Engineering Technique to Optimize Defensive Fire Protection Strategy

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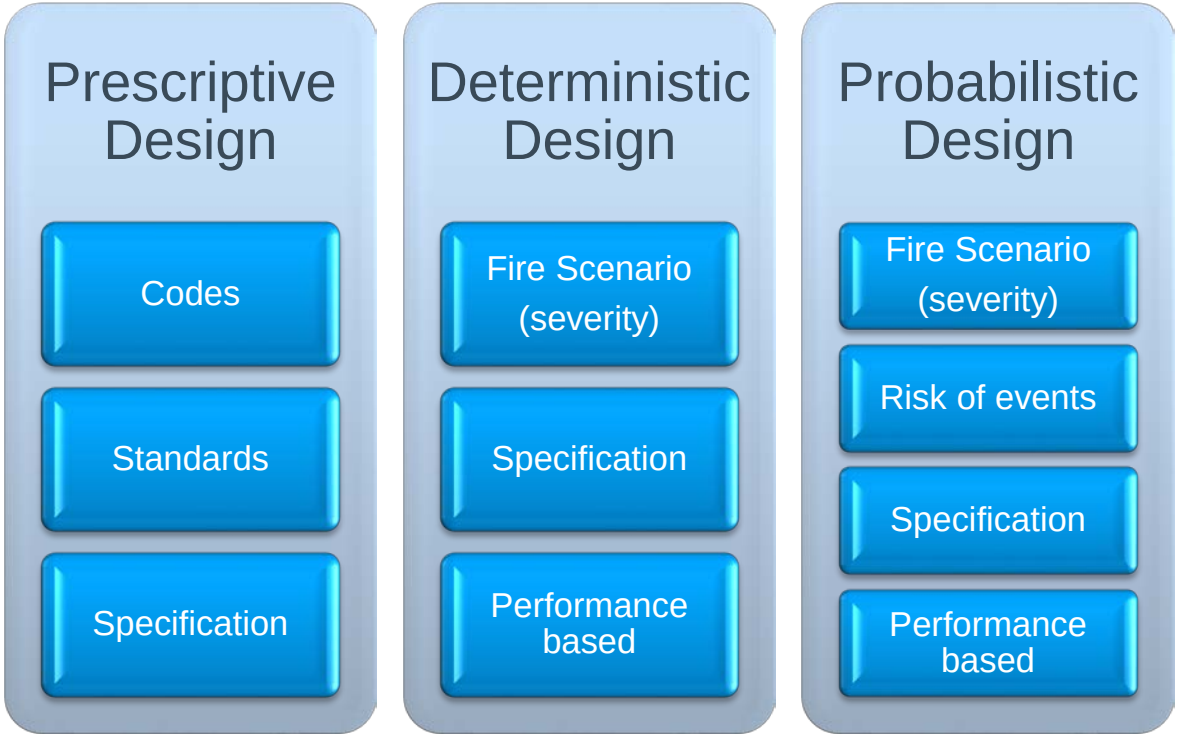
Fire Protection Design



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Deterministic vs Probabilistic

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NFPA 551 Definitions:

Deterministic Model:

In a deterministic model, the quantities being modeled are treated as being completely certain — the purpose of the model is to provide an estimate of these quantities.

Probabilistic Method:

In a probabilistic model, the quantities being modeled are treated as being uncertain — the purpose of the model is to quantify the degree of uncertainty in these quantities.

Defensive Fire Protection

NFPA 600 Definitions:

Defensive:

The mode of manual fire control in which the only fire suppression activities taken are limited to those required to keep a fire from extending from one area to another.

Offensive:

The mode of manual fire control in which manual fire suppression activities are concentrated on reducing the size of a fire to accomplish extinguishment.

Risk Based Fire Protection Design

Event Tree Analysis

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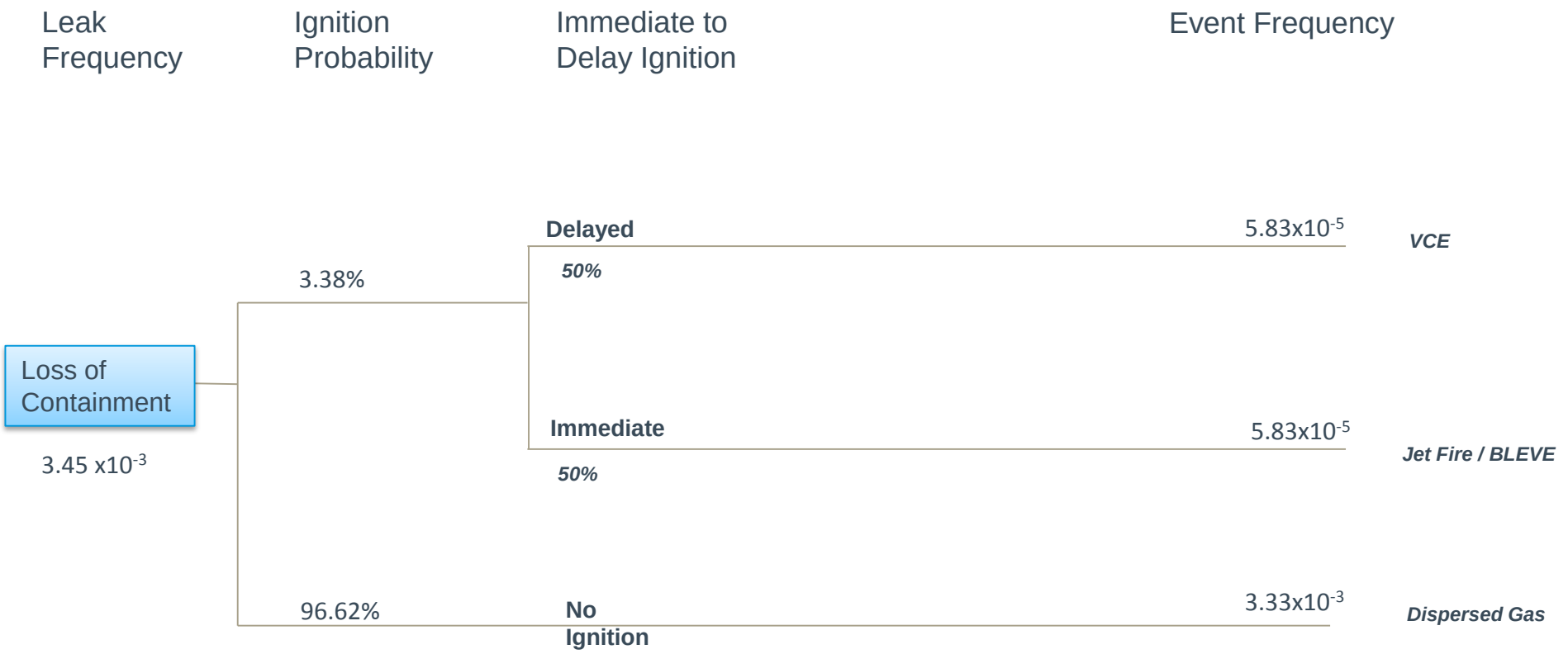
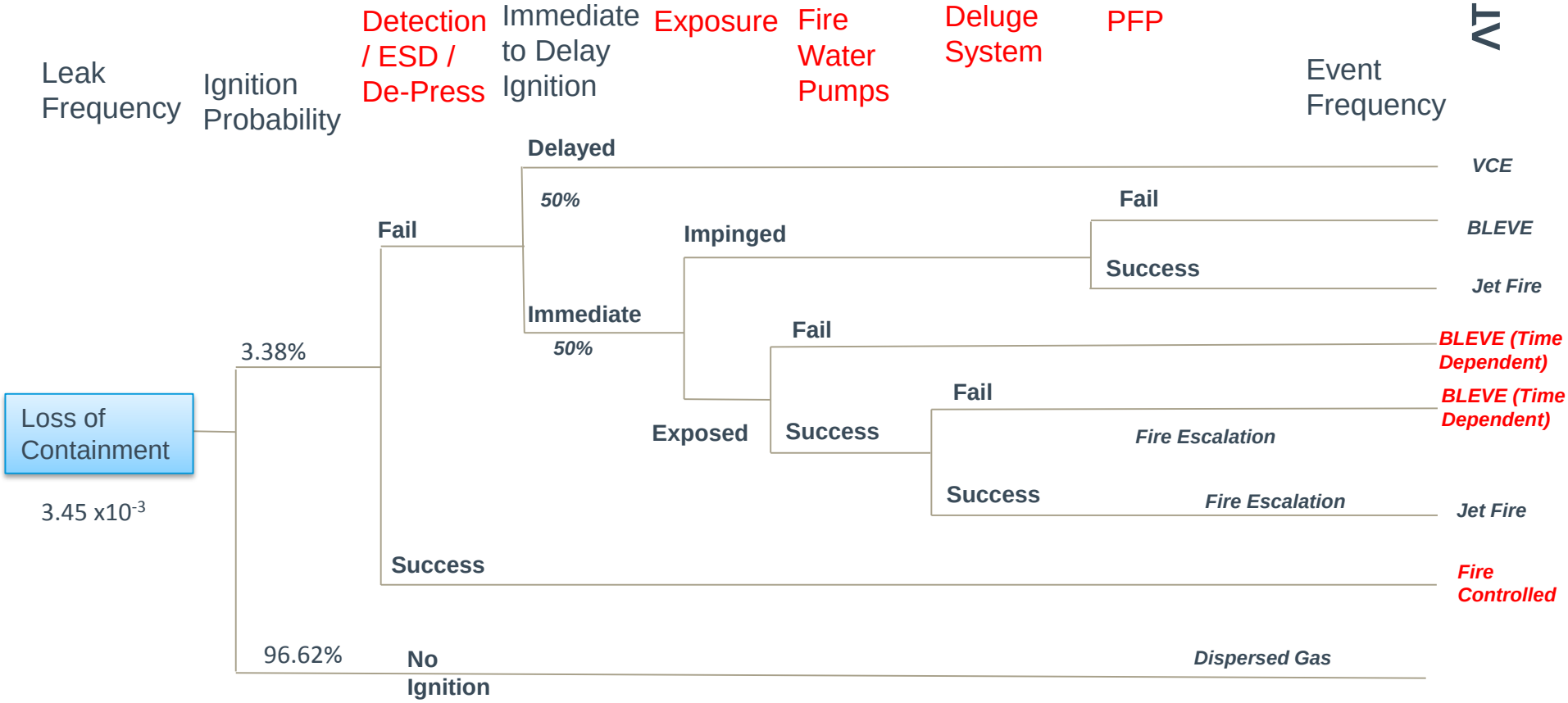


ETA with Barriers



Reliability of Barriers

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Reliability of the barriers depends on:

- failure frequency
- test intervals,
- mean time to restore (MTTR) and
- diagnostic coverage.

$$PFD \approx \lambda_{DU} \cdot \tau / 2$$

Failure on Demands

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Type of Barriers	Failures (per 10^6 hr)	Test Interval (yr)	Calculated PFD	Selected PFD (Based on Industry Practice)	Remarks
Gas Detector (IR)	2.26	1	4.49×10^{-3}	3.07×10^{-3}	Test interval every 3 months. However, standard test interval is every year
Fusible Link				1×10^{-6}	Reference: Grosse et al (1996)
Deluge System	5.8	1	1.27×10^{-2}	1.5×10^{-2}	Selected PFD is based on OGP
Diesel Fire Water Pump	1550.38	0.02 (Per NFPA weekly)	0.133	0.12	Poorly Maintained Diesel pump is 0.12
Passive Fire Protection				0.01	CCPS
Emergency Shutdown Valve	6.5	1	2.89×10^{-3}	2.89×10^{-3}	
ESD Logic Solver	16	Unknown	3.5×10^{-2}	3.5×10^{-2}	Test Interval is normally 1 yr

Effectiveness of Barriers

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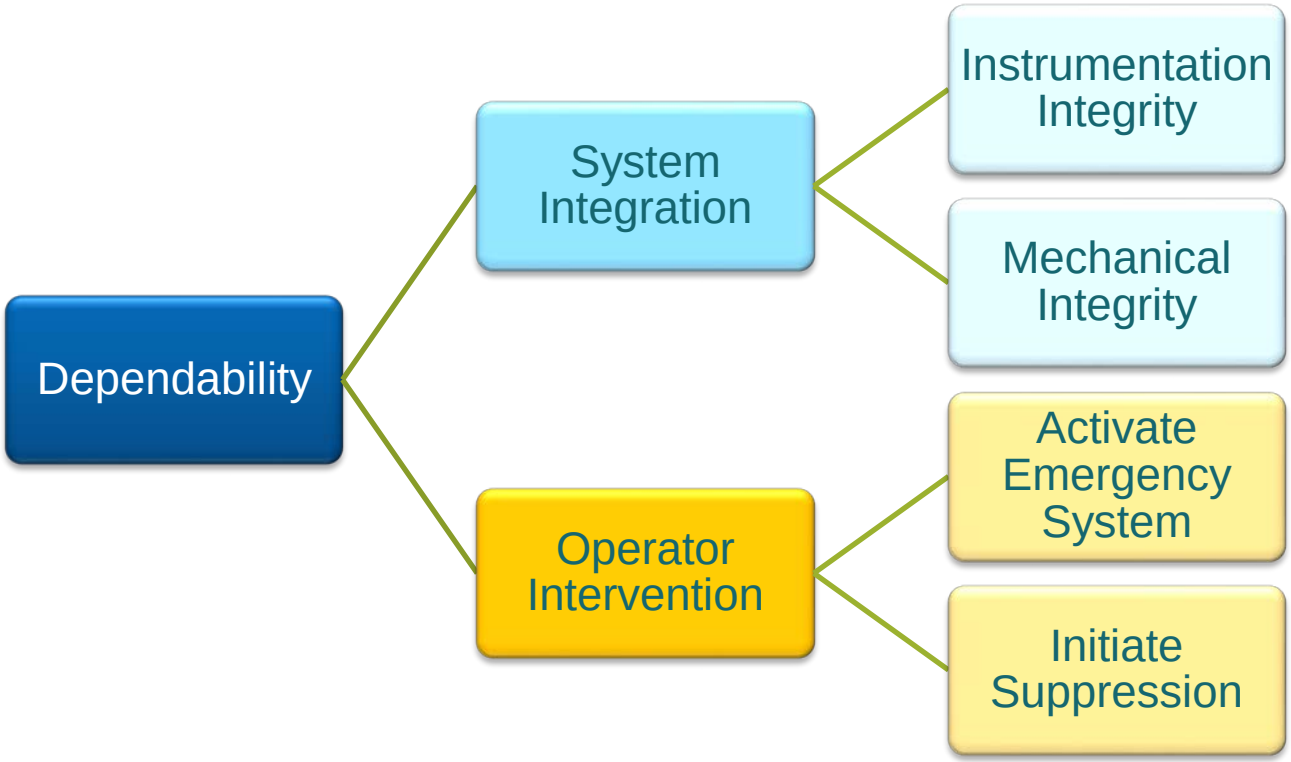
Effectiveness of barriers and safeguards should be evaluated by considering the following elements:

- Functionality;
- Maintenance History;
- Voting Logic; and
- Dependability.

Dependability



Dependable Equipment Impairment

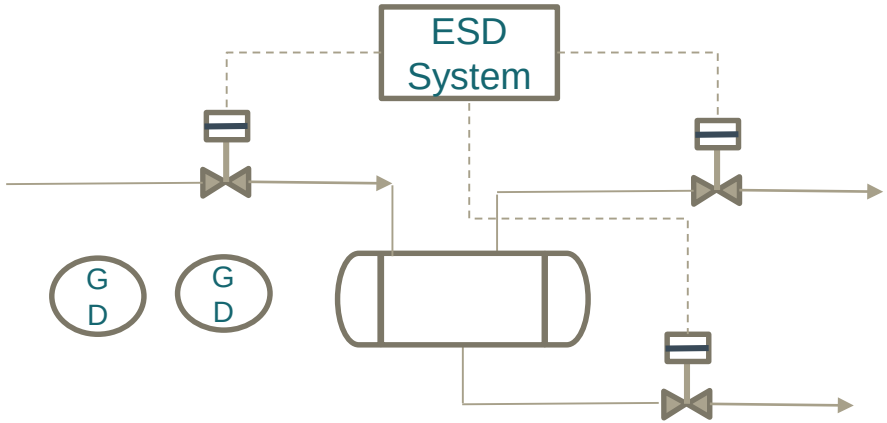
Maintenance Condition & History

Functionality

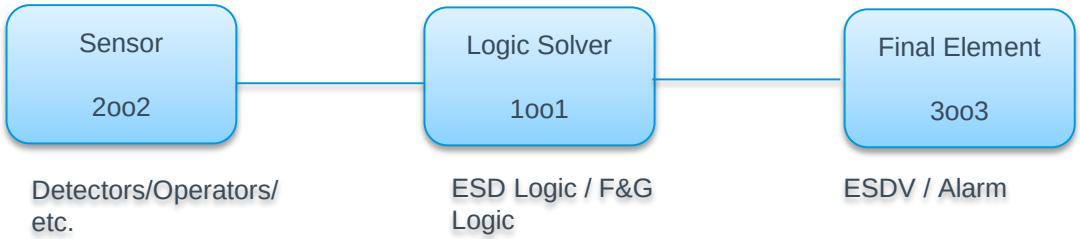
- Deluge for BLEVE impingement (PFD=1)

- Using Improper type of fireproofing or jacketing (PFD=1)

Voting Logic



PFD = 4.98 x 10^{-2}



Voting Logic

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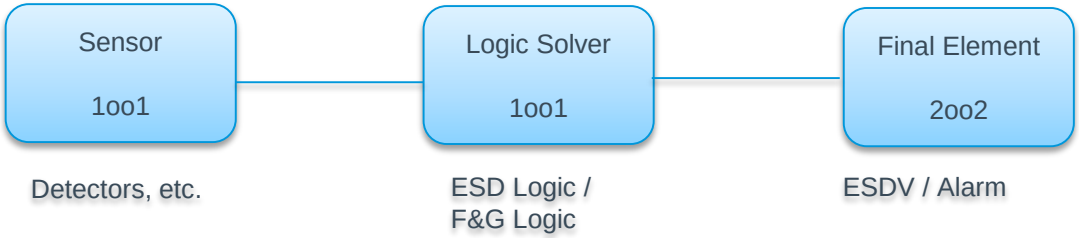
No Depressurization



PFD = 4.70×10^{-2}

Operator Intervention

PFD = 1.41×10^{-1}

Case Study: NGL Bullets

Fire Protection System:

No PFP
No F&G
No De-Pressurization
Poor Firewater system

Consequence Analysis Results

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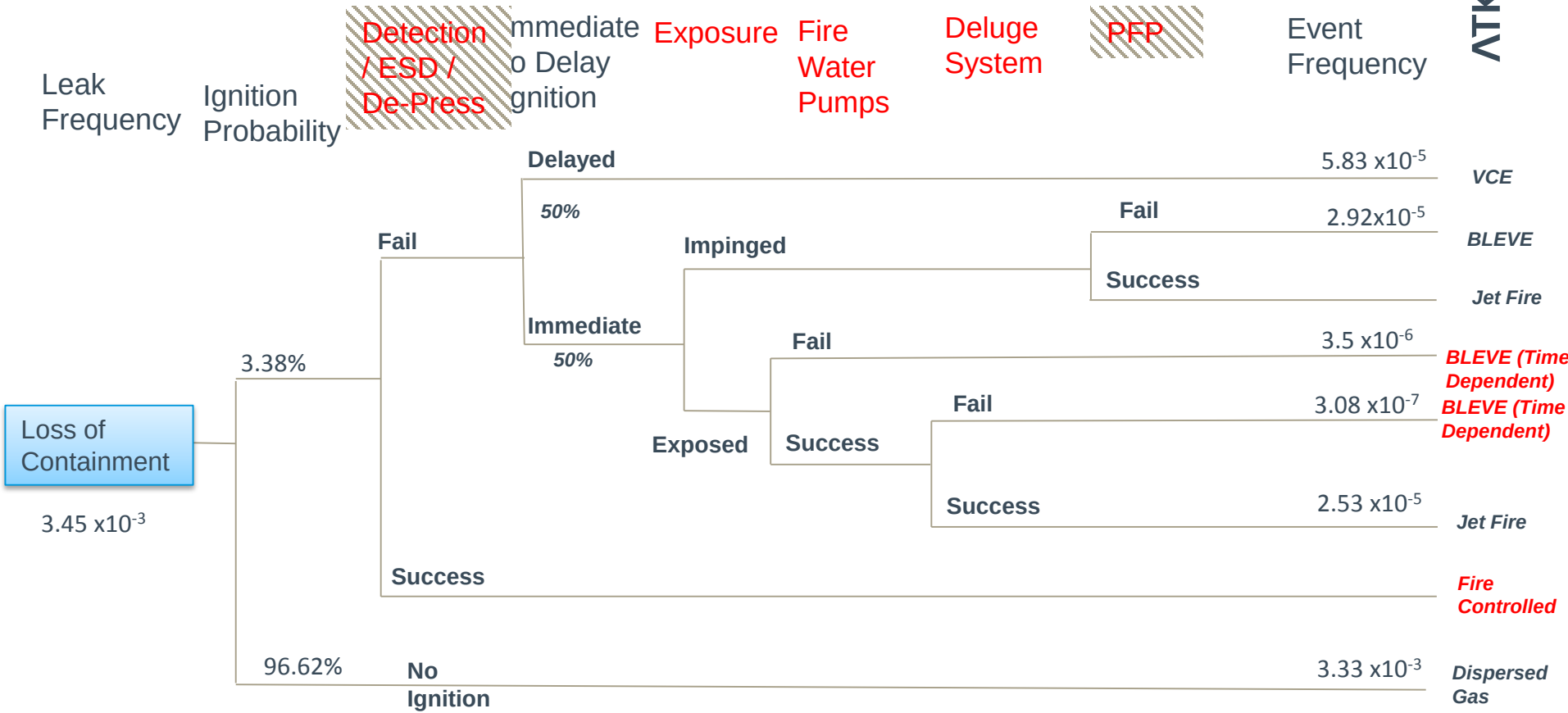
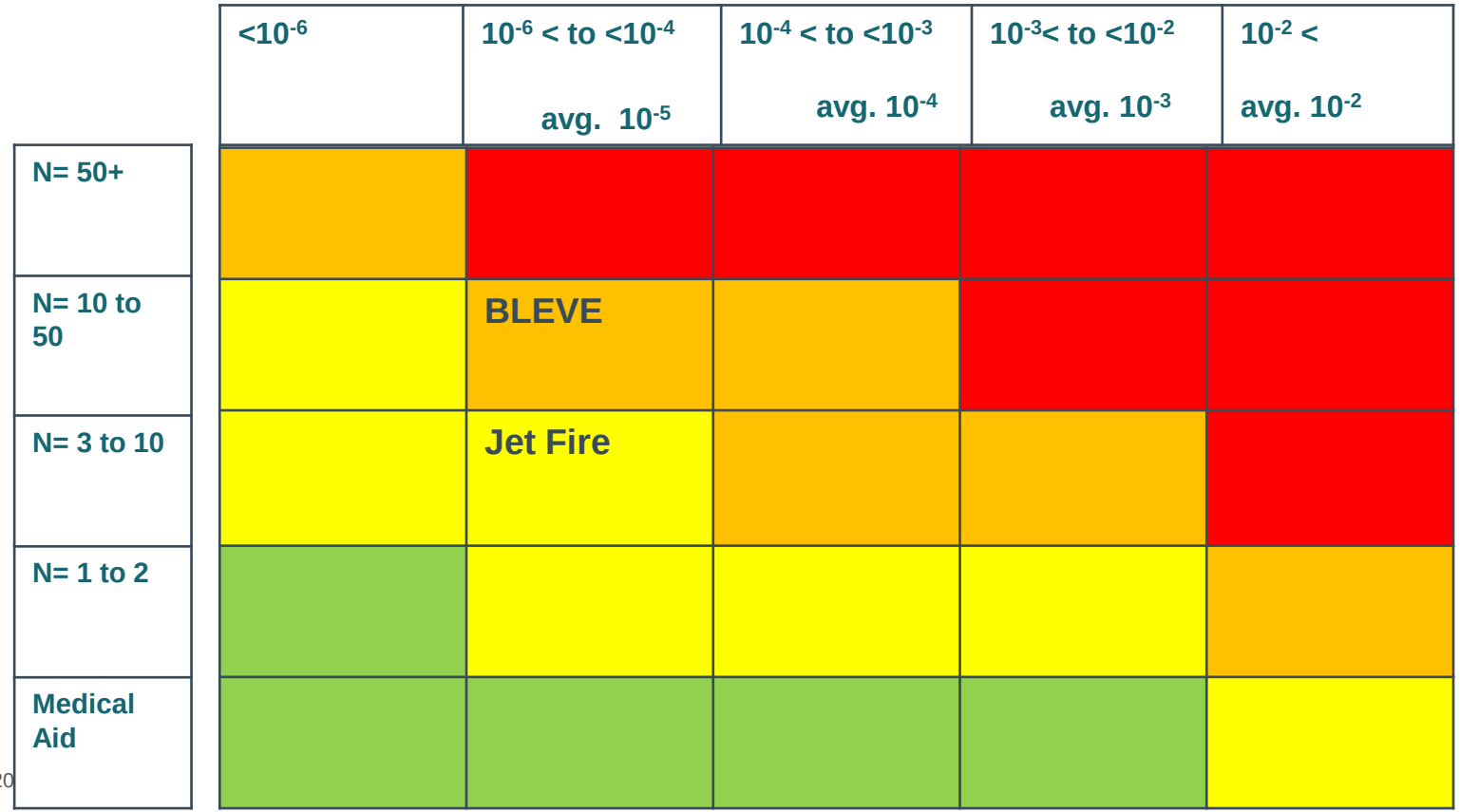
Event	Threshold	Impact Distance	# Fatality
BLEVE Fireball Distances (m) at 1 m above Ground	1000 tdu	196 m	
	2000 tdu	123 m	
	3200 tdu (%100 Fatality)	72 m	5*
Jet Fire	35 kW/m^2 (%100 Fatality)	46 m	5*
Overpressure	5 psig (%100 Fatality indoor)	64 m	5*
Overpressure	7.5 psig (%50 Fatality indoor)	51 m	2.5*

* Assume 10 workers/operators are working outdoor and 5 operators inside the building.

Original ETA



Risk Plotting



Defensive Fire Protection Design Options

1. Emergency Systems (ESD, F&G, Depressurization)
2. Passive Fire Protection
3. Emergency systems + Active Fire Protection
4. Emergency system + Passive Fire Protection

Improvements

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Improvement	Improvement	Existing PFD	Improved PFD
Firewater Diesel Pump		0.12	0.065
Deluge Valve tests Interval	From 3yrs to 6 months	0.015	0.0063
Detection system Valve tests Interval	From 1 yr to 6 months	4.95×10^{-3}	2.5×10^{-3}
ESDV test interval	From 1 yr to 6 months	2.9×10^{-3}	1.5×10^{-3}

Improve Risk Frequency

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Event	1 Detection/ ESD/ Depress.	2 Passive Fire Protection	3 Improved F&G/ESD/ Depress. & AFP	4 Improved F&G/ESD/ Depress. & PFP
VCE	2.9×10^{-6}	5.83×10^{-5}	1.36×10^{-6}	1.34×10^{-6}
BLEVE	2.9×10^{-6}	5.83×10^{-8}	7.15×10^{-7}	1.34×10^{-9}
Jet Fire	N/A	5.82×10^{-5}	6.2×10^{-7}	1.33×10^{-6}
Controlled Fire	1.11×10^{-4}	N/A	1.14×10^{-4}	1.14×10^{-4}
BLEVE Event Frequency	2.9×10^{-6}	5.83×10^{-8}	7.15×10^{-7}	1.34×10^{-9}

Improved Risk Plotting

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	<10^{-6}	10^{-6} < to <10^{-4} avg. 10^{-5}	10^{-4} < to <10^{-3} avg. 10^{-4}	10^{-3}< to <10^{-2} avg. 10^{-3}	10^{-2} < avg. 10^{-2}
N= 50+					
N= 10 to 50	Option 2,3 &4	Option 1			
N= 3 to 10					
N= 1 to 2					
Medical Aid					

What would change the results

- Risk matrix structure
- Type of Fire
- Population Distribution
- Spacing, siting, building type
- Equipment arrangement
- Mechanical Integrity Program

Thank you

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