A CORUÑA | 2016 | OCTOBER | 12th - 14th

II CONGRESO INTERNACIONAL de SEGURIDAD INDUSTRIAL en PUERTOS

II INTERNATIONAL CONGRESS of SAFETY in PORTS

Puertos del Estado

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PRESENTACIÓN - INTRODUCTION

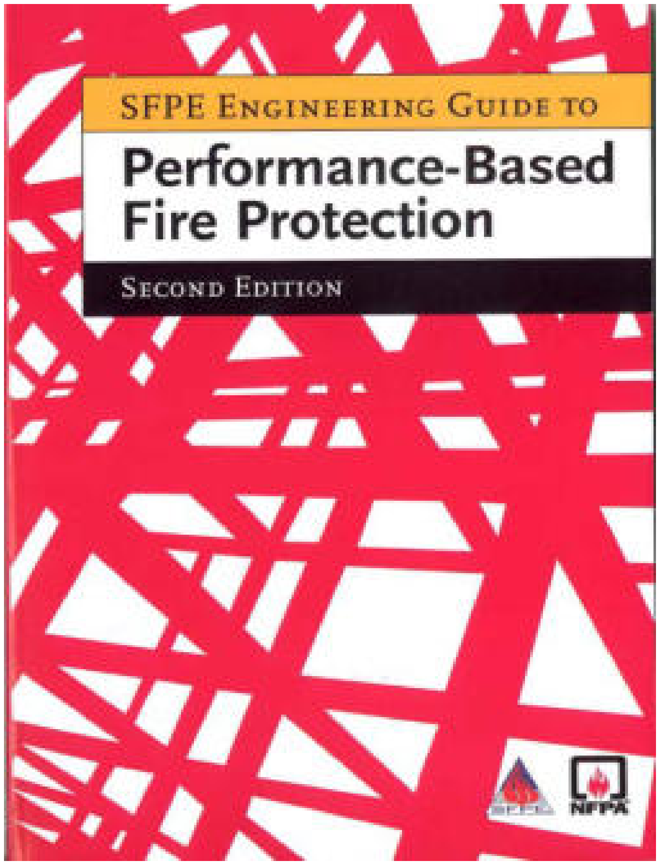
Brian Meacham

- Brian is an Associate Professor, Fire Protection Engineering, Worcester Polytechnic Institute, USA.
- His research focuses on risk-informed performance-based approaches to engineering and regulation.
- Prior to joining WPI his positions included Principal at Arup, Technical Director and Research Director at SFPE.
- Brian is Chair of the SFPE Committee on Research, Technology and Methods, Chair of the US TAG to ISO TC92 SC4 – Fire Safety Engineering, Chair of the NFPA Technical Committee on Fire Risk Assessment Methods.
- He is a licensed Professional Engineer, a Chartered Engineer and Fellow of the IFE, a Fellow of SFPE, and a Fulbright Scholar.

- Risk-Informed Performance-Based Design: Concepts and Applications to High-Challenge Facilities
- What Does Risk-Informed Mean?
- SFPE Performance-Based Design Process
- Representative Tools & Data for a Risk-Informed Process
- Case Study

- Risk considers likelihood and consequence
- A risk-based approach uses quantified values of risk as the sole basis for a decision.
- Risk-based approaches include
  - Quantified risk assessment (QRA), as used in the process safety area, some transportation areas, some environmental areas
  - Probabilistic risk assessment (PRA), as used in some nuclear power industries, aerospace applications, and similar
  - Reliability-based design approaches, such as LRFD and the EuroCode approach for structural engineering

- A risk-informed approach means we use concepts, tools and methods of risk analysis to provide context and information about a problem and potential solutions, including their efficacy, but that we do not base final decisions solely on a quantified risk value



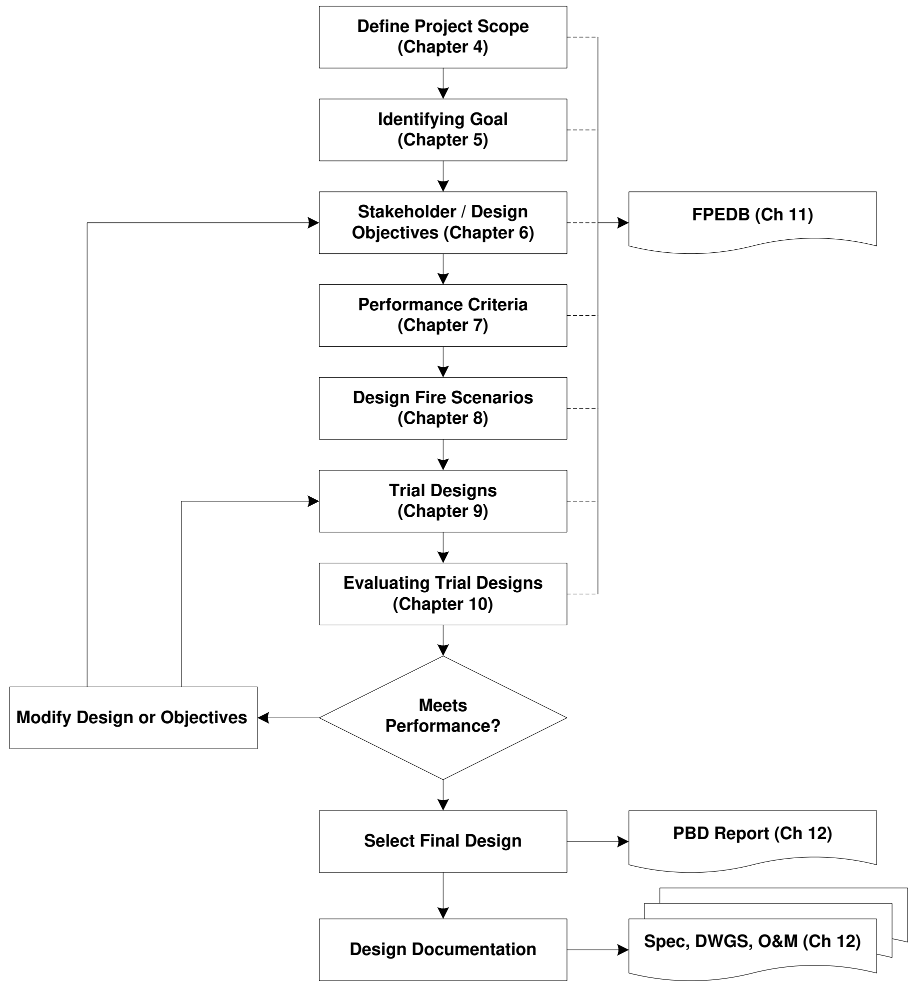
Performance-based fire safety design is an engineering approach based on

(1) established fire safety goals and objectives,

(2) deterministic and probabilistic analysis of fire scenarios, and

(3) quantitative assessment of design alternatives against the fire safety goals and objectives using accepted engineering tools, methodologies and performance criteria.

- Identify stakeholder goals
- Define stakeholder and design objectives
- Develop performance criteria
- Develop scenarios and fires
- Develop trial designs
- Evaluate trial designs
- Documentation



- Goal may be simple – protect life, property, business
- Objectives should be more detailed – measurable
- Can be helpful in assisting stakeholders define their objectives by asking: how large of a fire can you tolerate – what extent of damage / loss is acceptable?
  - No loss of life due to fire,
  - No local or global collapse due to fire,
  - Limit downtime of equipment / processes to 8 hours,
  - Building must be reoccupied within 48 hours,
  - Maximum fire-related loss of $100,000

- Develop acceptance criteria
- In deterministic design, these might be temperatures, radiant heat fluxes, smoke levels above floors, etc. Risk-based or risk-informed design may use these as well, but not necessarily.
- Instead, one might select probability of a particular unwanted event as criteria (e.g., 1x10-6 probability of a fatality from fire, or 1x10-6 probability of downtime due to fire exceeding 1 week, …)

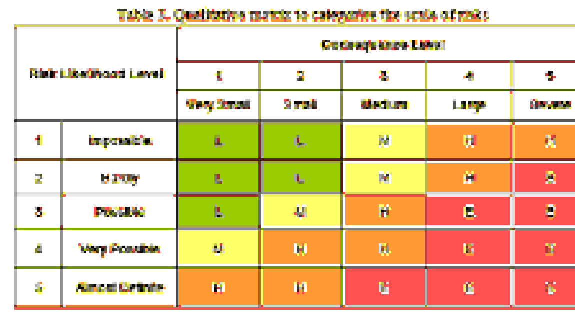
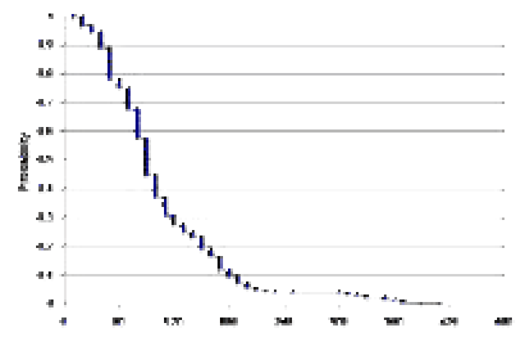
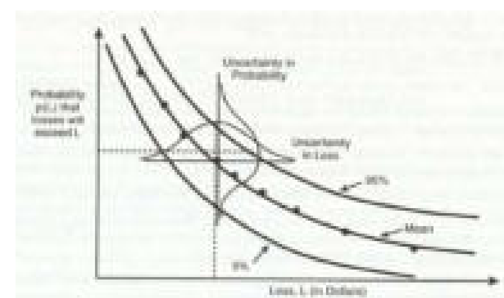


Table 3. Qualitative matrix to categorize the scale of risks

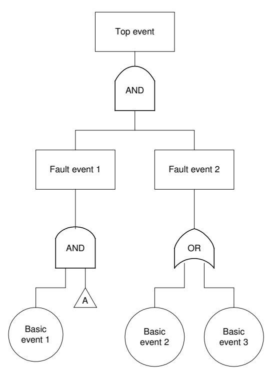
Risk Likelihood Level		Consequence Level				
		1	2	3	4	5
		Very Small	Small	Medium	Large	Severe
1	Impossible	L	L	M	H	H
2	Unlikely	L	L	M	H	E
3	Possible	L	M	H	E	E
4	Very Possible	M	H	H	E	E
5	Almost Certain	H	H	E	E	E

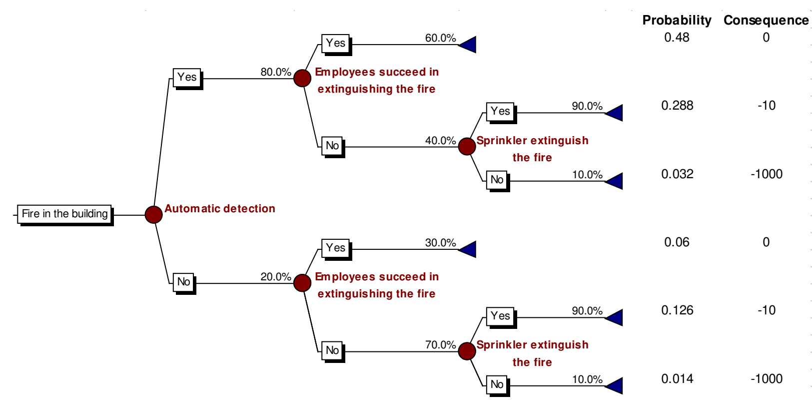




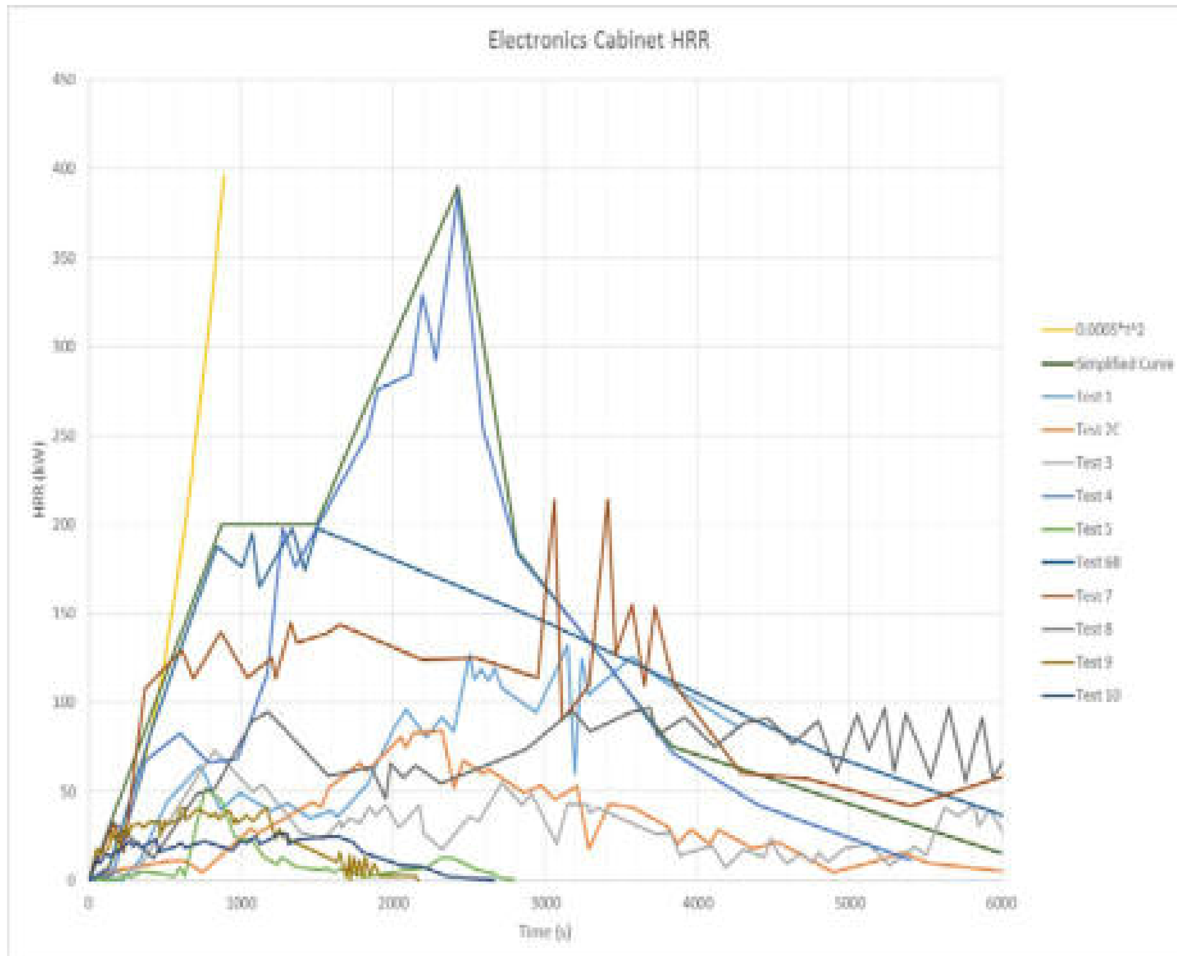
- Identify scenarios of concern
- Significant opportunity to use risk assessment concepts & tools
  - Fire loss statistics
  - Fire investigation reports
  - What if analysis
  - FMECA
  - Fault tree analysis
  - Event tree analysis
  - RAMS analysis

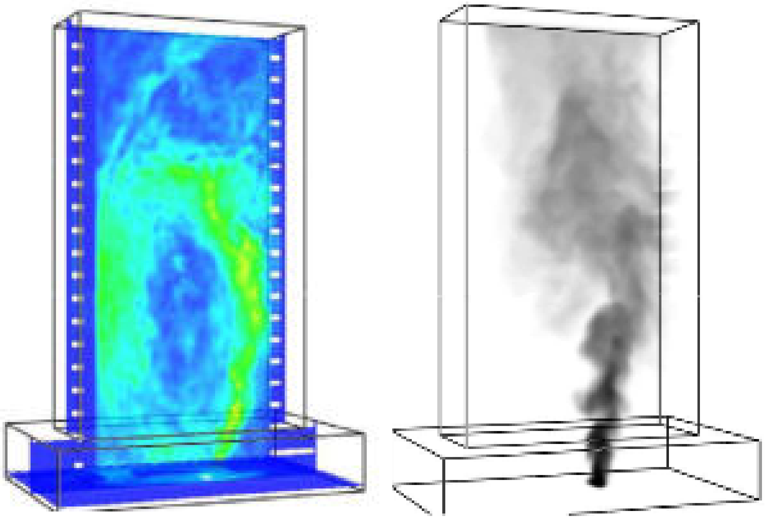
Item	Failure Mode	Cause	Effect	Criticality
Fuel Tank	Rupture (mechanical)	a. Poor workmanship (e.g., weld failure) b. Defective materials c. Impact damage	Release of liquid and potential fire	Moderate (3)
	Rupture (fire exposure)	a. Thermal impact to tank shell	Massive fireball	Extreme (5)
		b. Overpressure due to undersized relief valve		

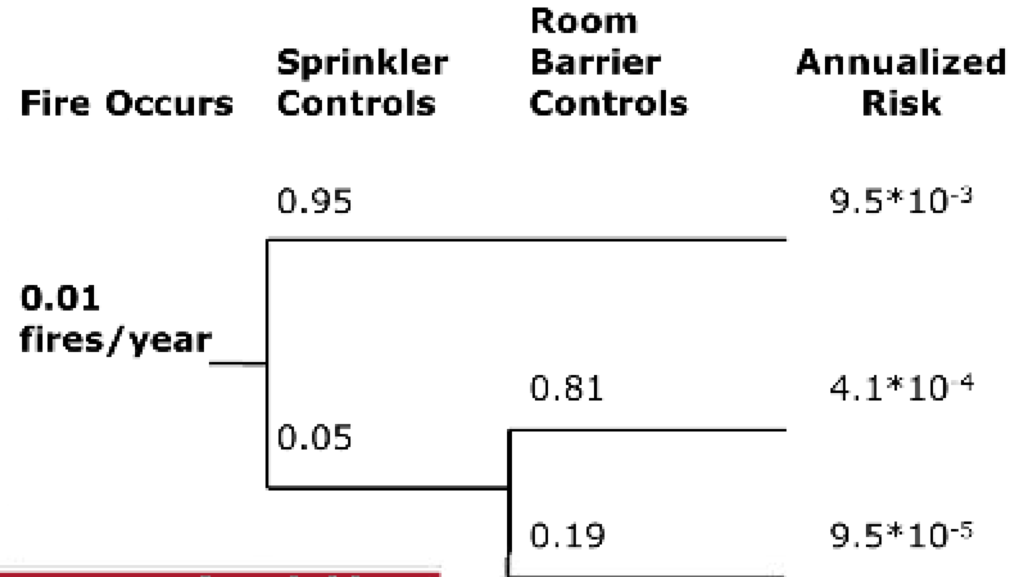




- Identify design fire(s) for consideration
- Can result from fire loss history, research, fire tests, modeling







Cause	Percent of Sprinkler Failures
Equipment shut off	64%
Manual intervention defeated the equipment	17%
Component was damaged	7%
Lack of maintenance	6%
System inappropriate for type of fire	5%

- Study case – Miami International Airport, CRC & QTA Facility
- Intent was to connect transportation systems and create transportation hub to service the Miami International Airport (MIA)
- Includes light rail, bus, automated people mover, and consolidated rental car facility
- To increase efficiency of consolidated rental car facility (RCF), it was desired to include quick turn around (QTA) facility for refueling and washing of rental cars as part of RCF

- Goals
  - 190,000 m2 of parking
  - 120 fueling stations
  - Quick turn around time
- Challenges
  - Code allows only four (4) fueling stations on first level within 50 feet of exterior wall
  - Entire site would be needed for First Floor Quick Turn Around (QTA)
  - Onerous operational model, i.e. costly and poor efficiency

- Risk-informed performance-based approach
  - Stakeholder workshop
  - Agreed goals, objectives and criteria
  - FEMCA, fault tree analysis (FTA) and event tree analysis (ETA) to determine failure modes in gasoline system, at fueling stations, etc., as well as to look at accident scenarios and resulting events
  - Fire effects modeling
  - Explosion modeling
  - Evacuation modeling

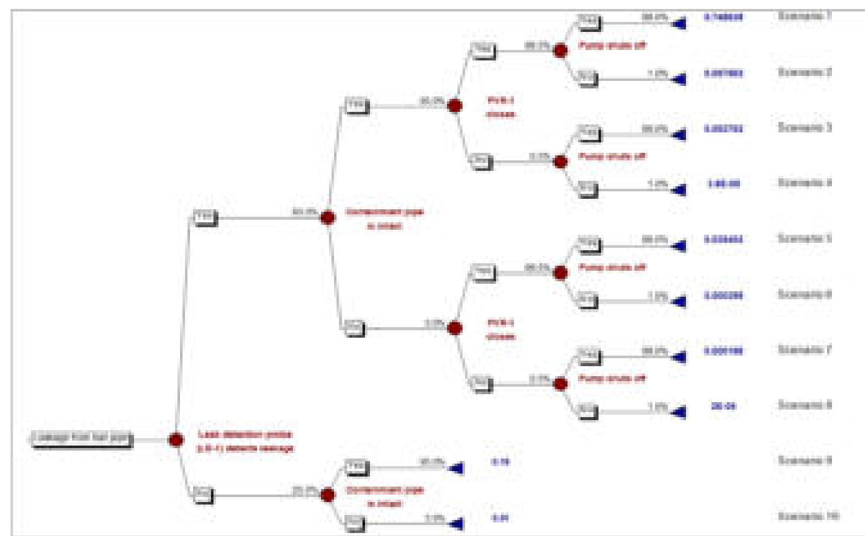
- Goals: protection life, property, mission and the environment
- Representative stakeholder objectives (more than 20 in total)
  - Limit any fire initiating in a vehicle to the vehicle of origin (i.e., no ignition of proximate vehicles).
  - Limit a fire initiating at a fuel dispensing station to that station and the immediate area surrounding it.
  - Limit any fuel release to a single level of the QTA.
  - Limit any single fire or explosion to the QTA level of fire or explosion.
  - Limit any fuel release to no more than could be expected by an interior fuel system design that complies with NFPA 30A.

- Representative design objectives
  - Design and construct the facility to withstand the maximum credible fire or explosion event, as developed during the HazOp and fire engineering analysis, for a period of time appropriate to comply with the above ALSB and stakeholder objectives.
  - Design and construct the structure to minimize the likelihood of fire spread beyond the item or area of fire origin (e.g., item if a vehicle, area if a pool fire).
  - Design and install explosive vapor detection system(s) to detect explosive concentrations when they reach 25% of the lower explosive limit and provide appropriate warning to occupants to allow reasonable time for occupants to evacuate the facility.

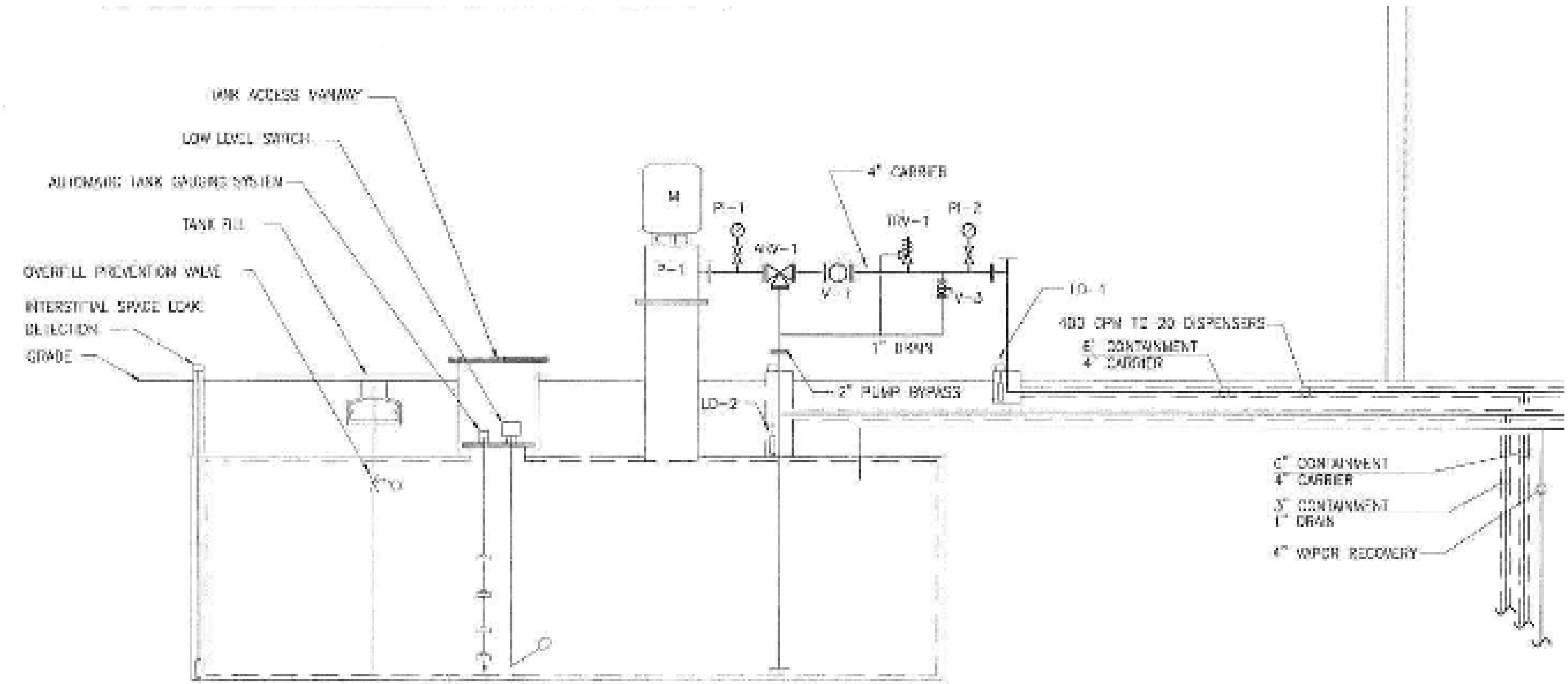
- Representative design criteria (note: project in year 2000)
  - Smoke layer not to descend below 1.8 m along the egress path during the time required for the occupants to reach a safe place.
  - Gas temperature and radiant flux exposure to occupants not the result in untenable conditions during anticipated exposure times. The gas temperature not to exceed 60 C and radiant flux not greater than 2.5 kW/m2 for 30 seconds.
  - For item-to-item fire spread within the involved space radiant flux between 25 and 35 kW/m2
  - For reducing the likelihood of vapor ignition in confined spaces such as pipe trenches and chases the vapor air concentration should be below 25 percent of the lower flammable limit (LFL)
  - Given a vapor ignition, the construction will withstand an overpressure 1.5 psi

Item	Identification	Description	Failure Modes	Effects	Criticality Ranking
Pump	P-1	Centrifugal pump	1) Fail to run 2) Fail to stop	1) No gasoline will be delivered to the QTA 2) Fuel will be circulated through the ARV-1 valve and back into the tank.	1 1
Indicator	PI-1	Pressure indicator with needle valve	1) Valve body ruptures 2) Leakage to external environment	1) See [A] above. 2) See [B] above.	3 2
Valve	ARV-1	Automatic recirculation valve	1) Fails to open 2) Fails to close 3) Valve body ruptures 4) Leakage to external environment	1) Dispensers will not receive enough fuel. 2) Pump will be operating at "dead head" 3) [A] Fuel will be released during approximately 15 seconds until the pump shuts down due to signal from leak detection probe in containment area. 4) [B] Leakage of fuel to external environment.	1 1 3 2
Valve	V-1	Ball valve, flanged	1) Closed during operation of system 2) Valve body ruptures 3) Leakage to external environment	1) No fuel will be delivered to the QTA 2) See [A] above. 3) See [B] above.	1 3 2

- Identify fire scenarios
  - Loss data
  - What-if analysis
  - FMECA
  - Quantitative risk assessment / ETA
- Assess fire impacts
  - Performance based analysis
- Recommend mitigation
- Evaluate
  - Computational modeling



- Failure Modes Effects and Criticality Analysis (FMECA) on fuel system



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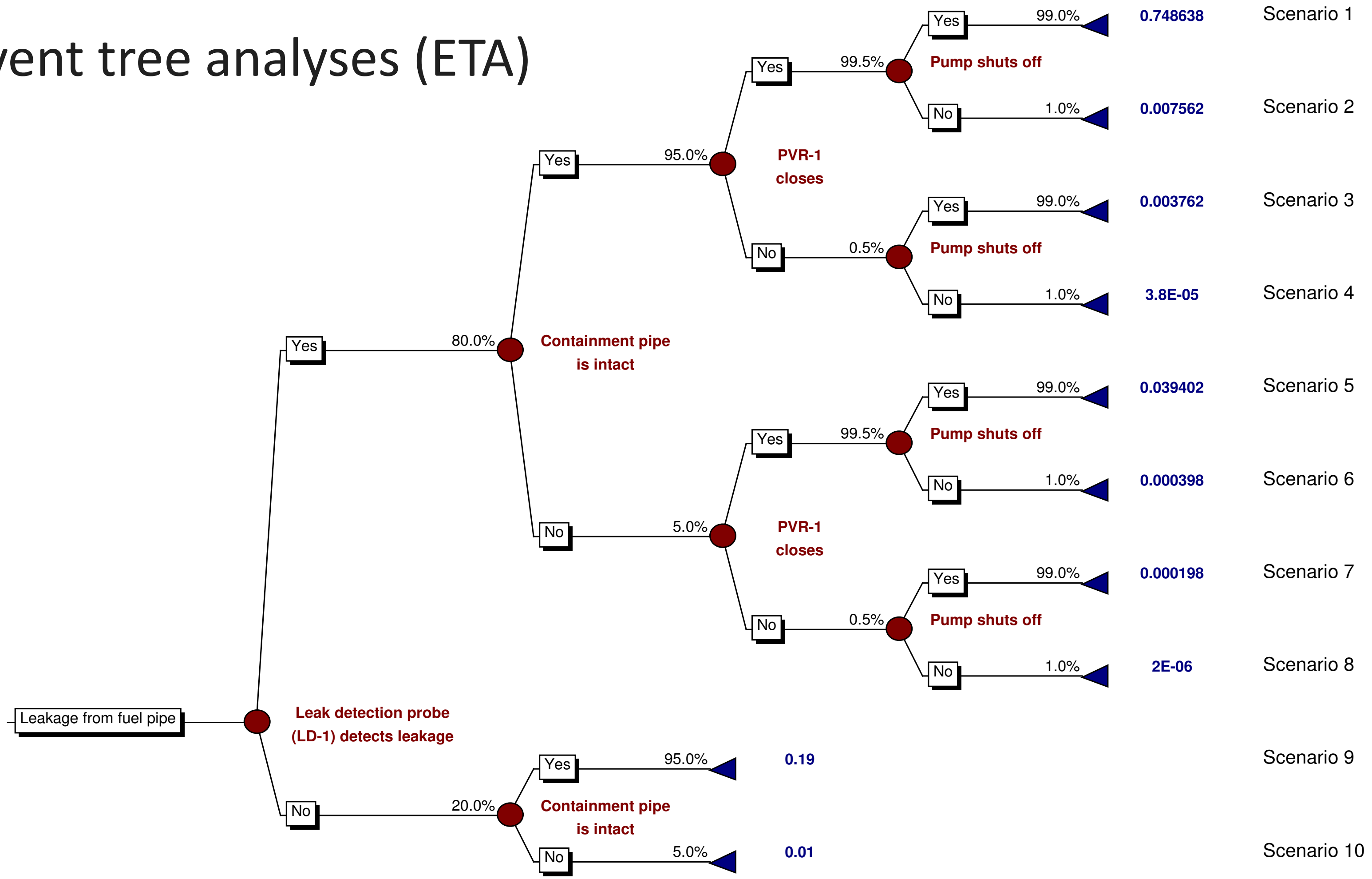
Event tree analyses (ETA)

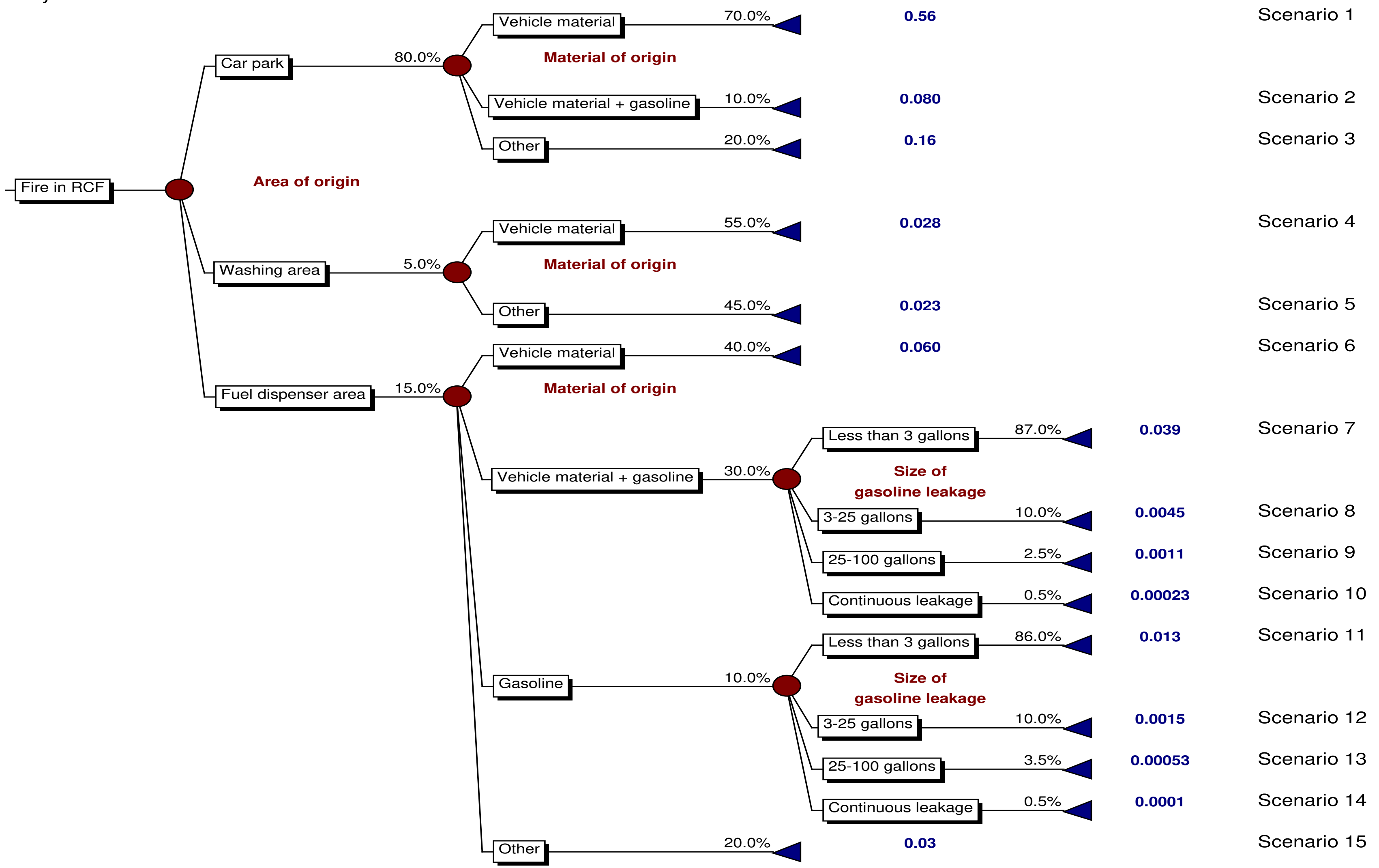


- For each scenario and each component (that can cause a release) an expected frequency was calculated.

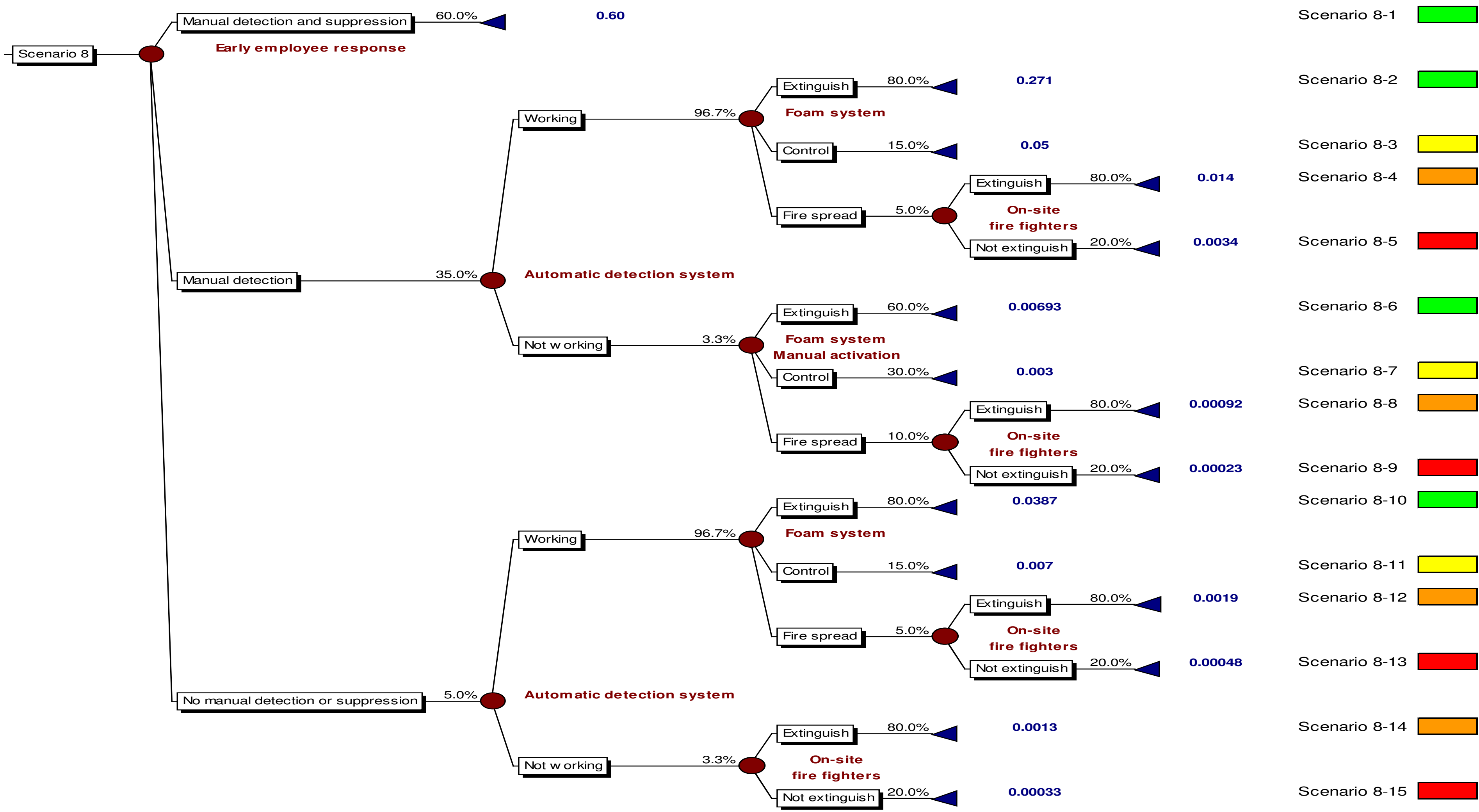
Event (in the trenches)	Frequency (per year)
Minor leakage from the fuel system	$3.5*10^{-6}$
Major leakage, employees notified	$1.8*10^{-10}$
Major leakage, employees not notified	$8.8*10^{-7}$

- Compare to annual probability of dying:
  - If person is a smoker: $3*10^{-3}$
  - In airliner crash (10 trips): $1*10^{-5}$
  - Being hit by lightning: $1*10^{-7}$

Primary scenario tree for a fire in the RCF



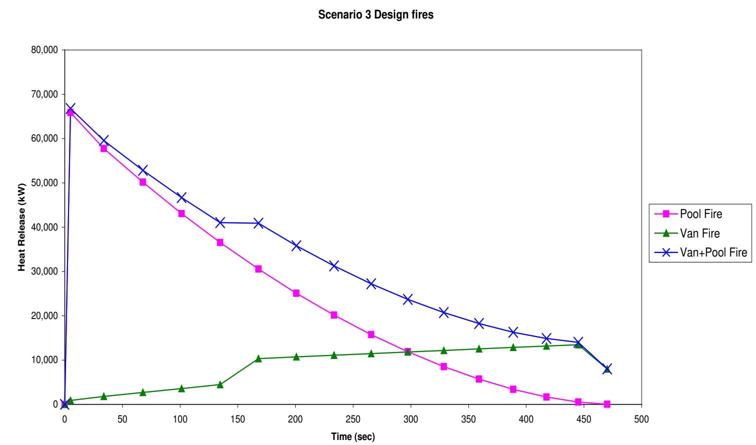
Scenario 8: A fire in a 3-25 gallon fuel spill at a fuel dispenser with a vehicle at the dispenser



Scenario group	Description of group	Estimated frequency (occurrences per year)	Estimated return period (years)
Group 1	The fire is extinguished by the employees or by some automatic suppression system.	0.052	19
Group 2	The fire is controlled by some automatic suppression system.	0.042	24
Group 3	The fire is not suppressed or controlled by any automatic suppression system or by the employees. The fire is extinguished easily by the fire department.	0.005	215
Group 4	The fire is not suppressed or controlled by any automatic suppression system or by the employees. A considerable fire fighting operation is required to put out the fire.	0.001	808

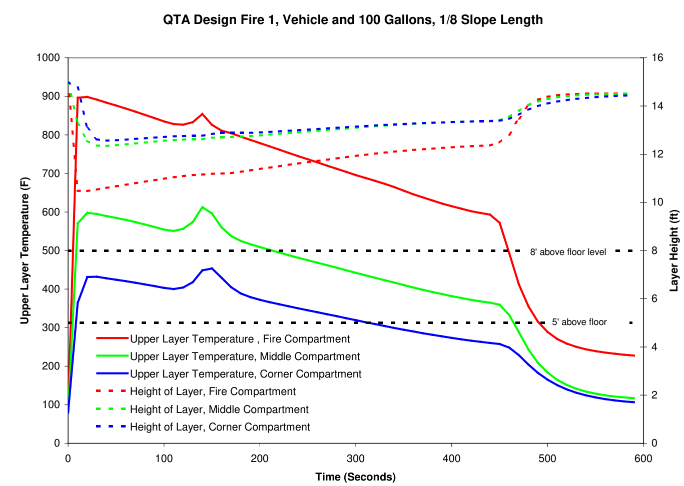
- Fire and Explosion Scenarios
  - Gasoline ‘pool’ fire
  - Vehicle fire
  - Combined ‘pool’ / vehicle fire
  - Other liquid ‘pool’ fire – other liquids determined to be less hazardous
  - Explosion Scenarios
  - Spill / evaporation vapor cloud
  - Trench vapor cloud – trench to be filled

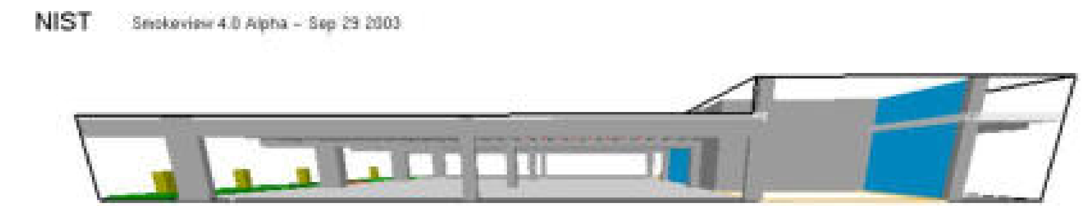
- Pool Fire (#1)
  - Non-draining retention area
  - 100 gallon gasoline spill
  - Based upon retention area
  - Calculations of nozzle throw distance

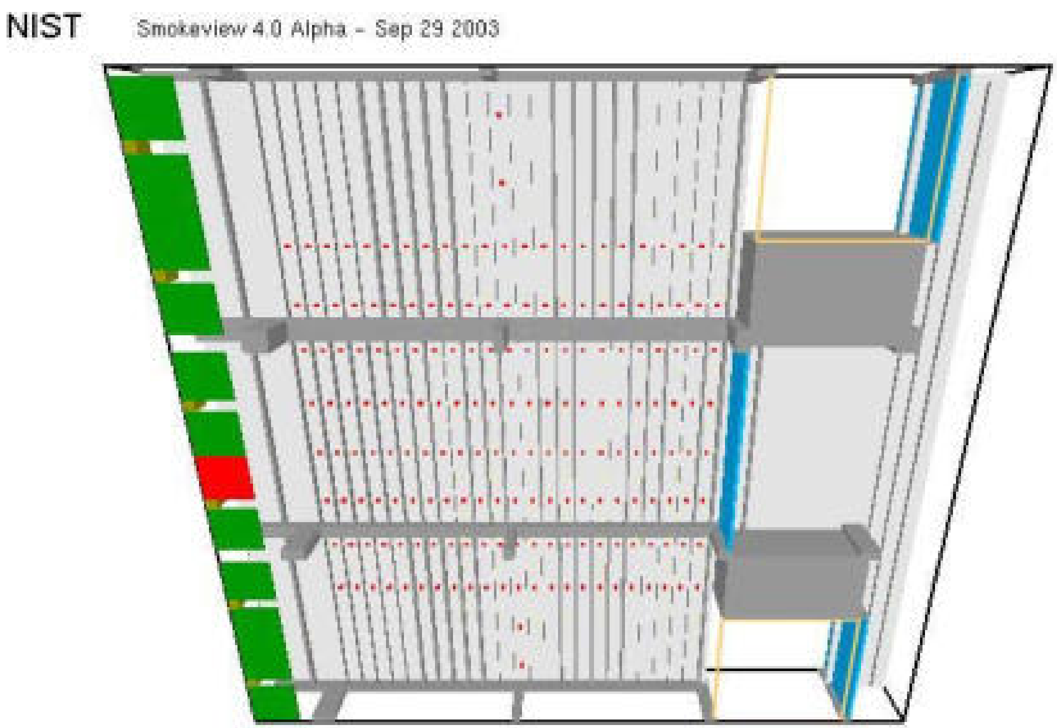


- Vehicle Fire (#2)
  - Various sized vehicles reviewed
  - Van determined severe scenario

- Vehicle Plus Pool (#3)




NIST
Smokeview 4.0 Alpha - Sep 29 2003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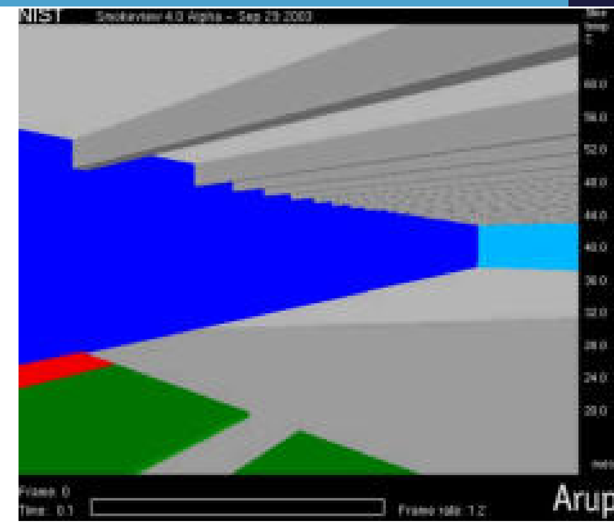
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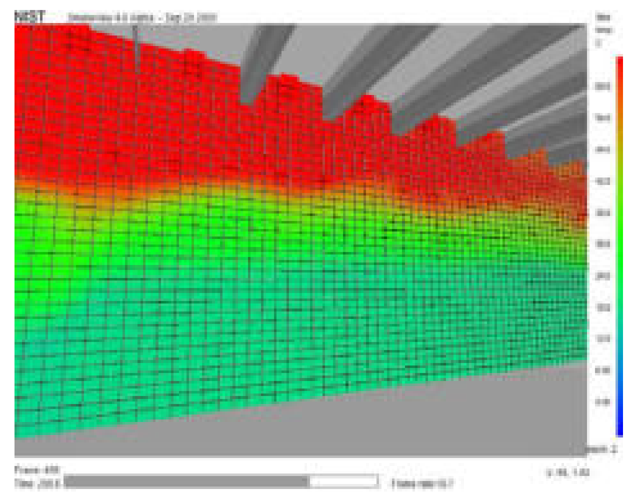
Arup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Temperature / Separation Analysis

Figure 7: Desing Fire-3 Plume Temperature at Ceiling

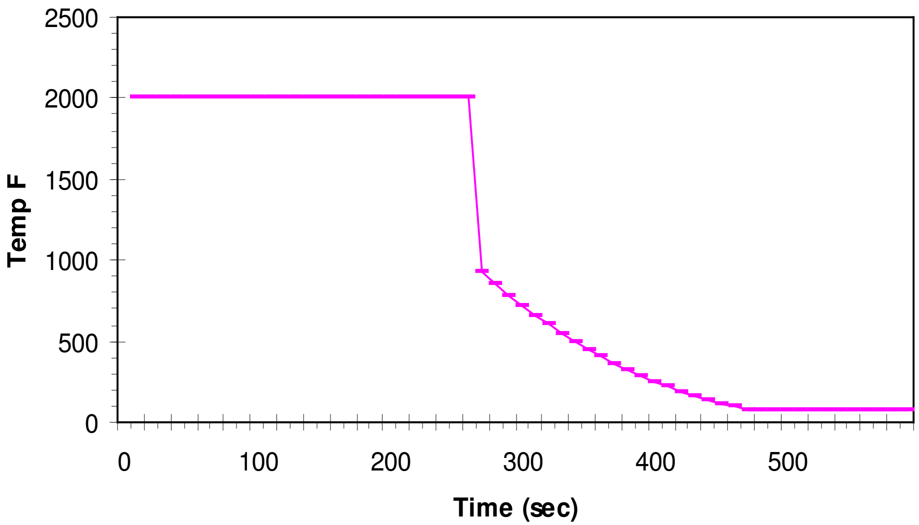
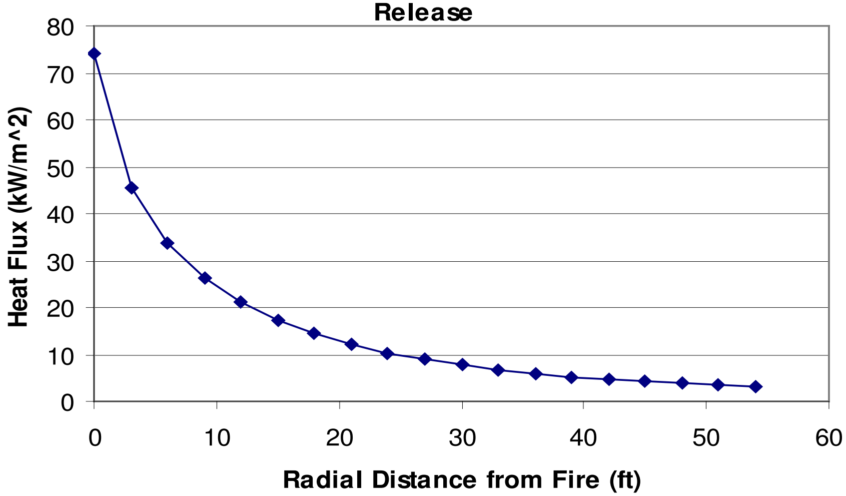
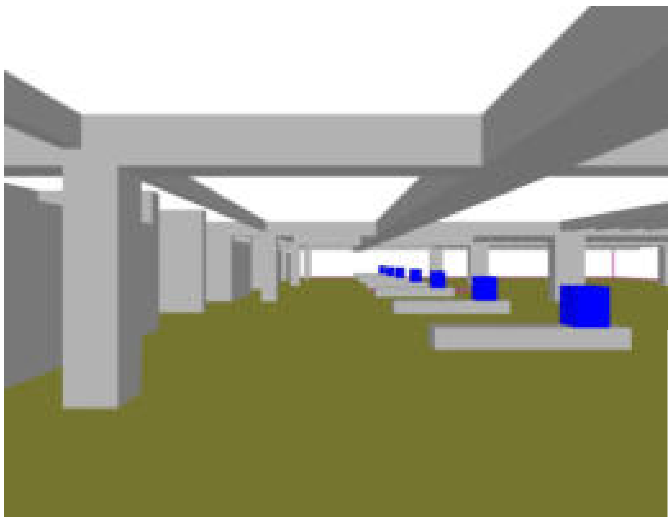
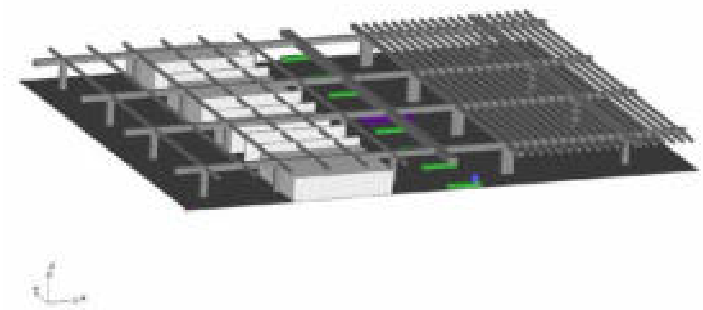


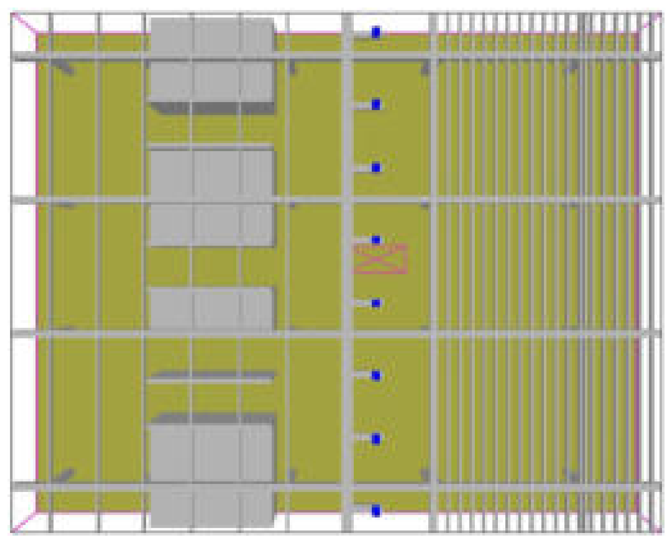
Figure 9: Radiaton From Design Fire-3 At Peak Heat Release



Explosion analysis – FDS and Fluent



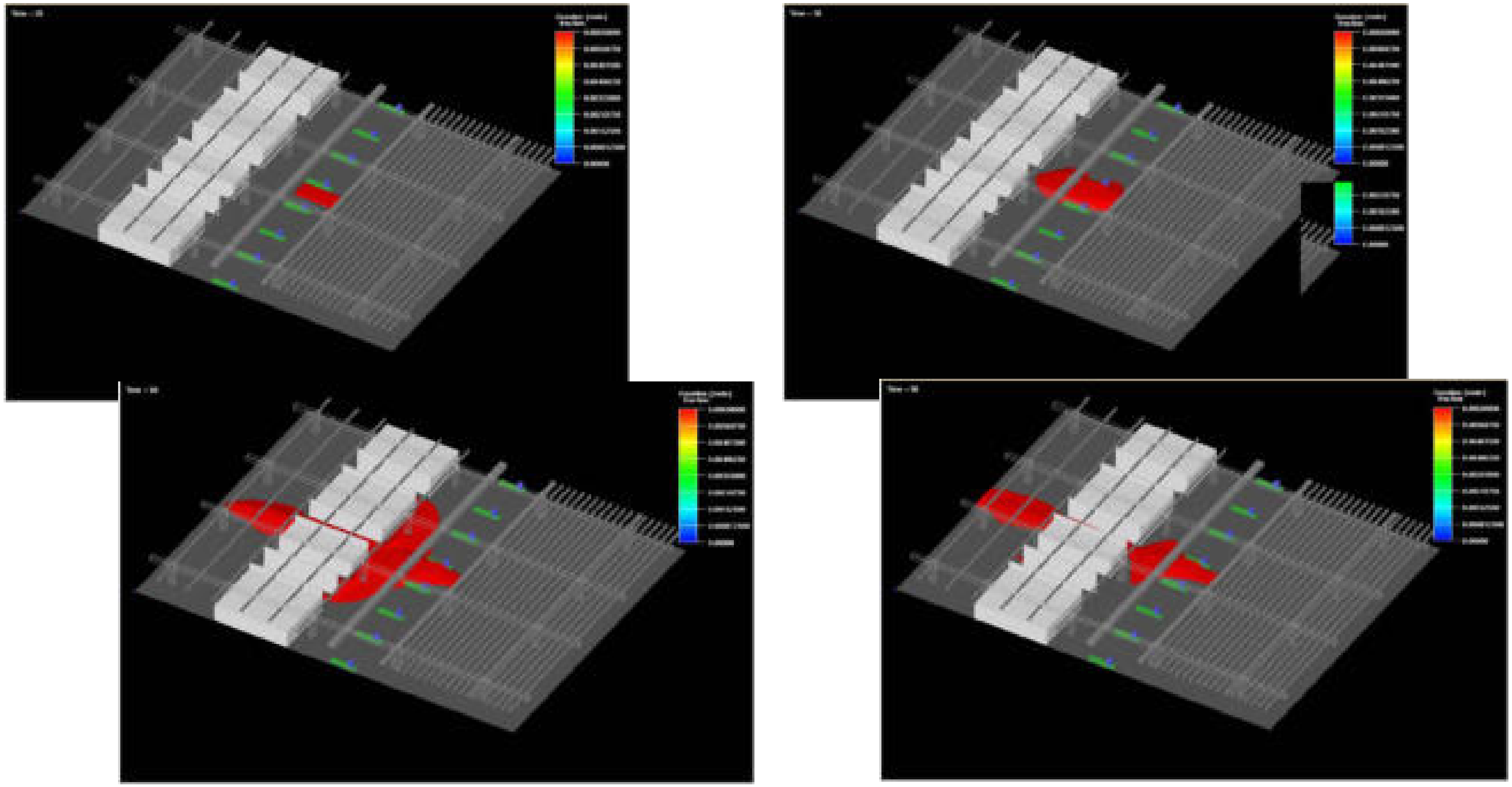




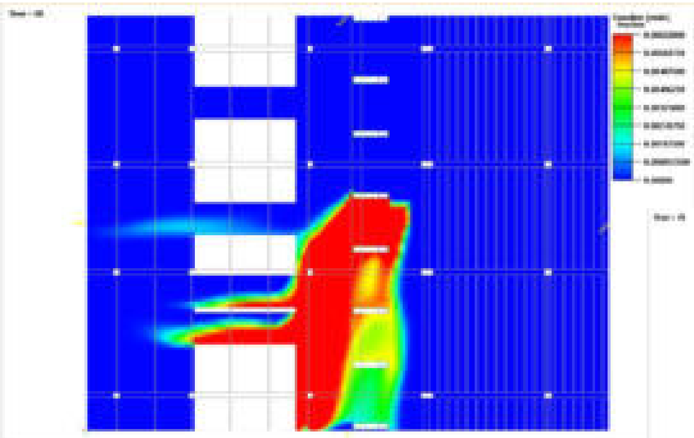
Explosive range of gasoline is 1.3-7% by volume

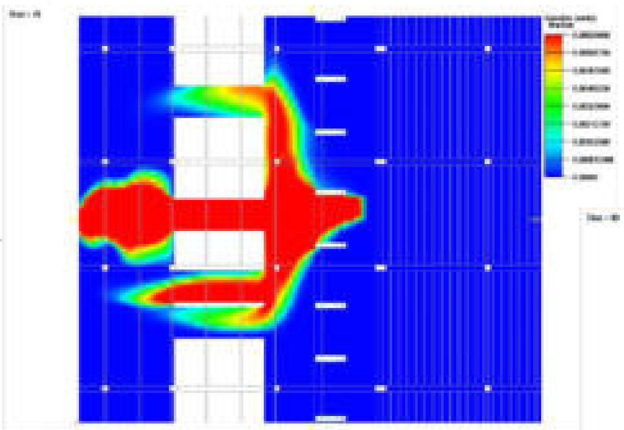
Analysis used 0.65 - 50 % of Lower Flammability Range – adds conservatism to the model

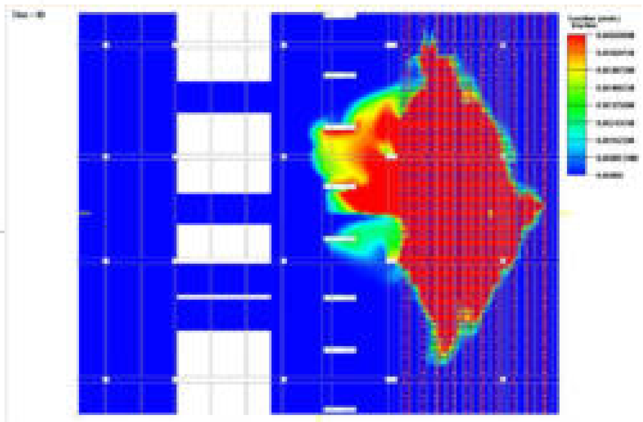
- Vapor Concentration – Dispersion



Vapor Dispersion – Wind Impacts

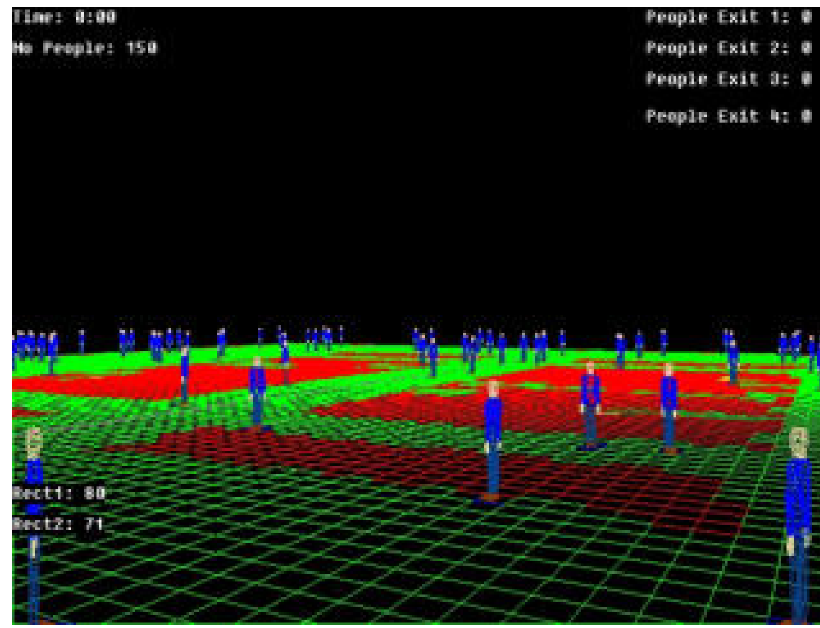




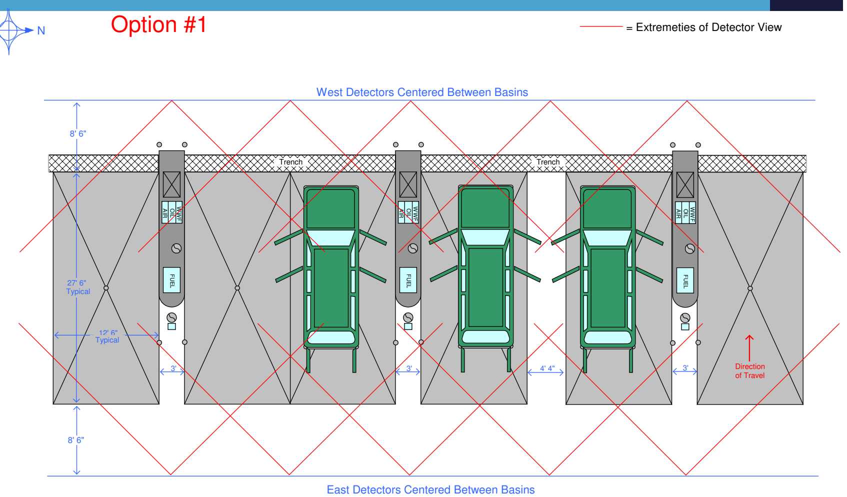


Evacuation Analysis – STEPS

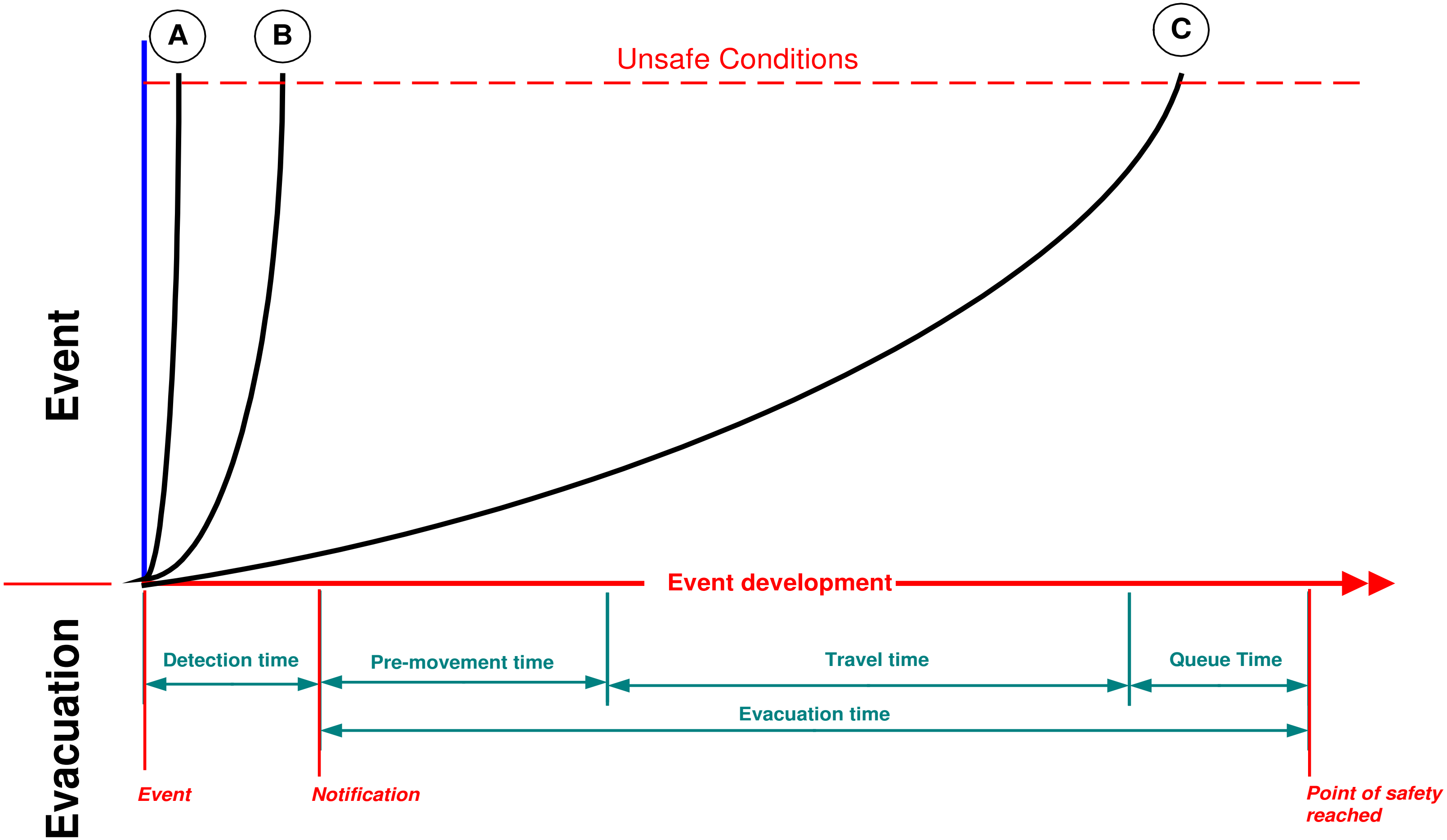
Occupants	W1	W2	W3
Awake - Familiar w/ Building	<1	3	>4
Awake - Unfamiliar w/ Building	<2	3	>6
Sleeping – Familiar w/ Building	<2	4	>5
Sleeping – Unfamiliar w/ Building	<2	4	>6
Require Assistance	<3	5	>8



- Mitigation recommendations
- Fuel Control
  - Retention areas with drains
- Fire Detection
  - UV/IR and heat detectors at refueling islands
- Fire Suppression
  - Overhead and floor level alcohol resistant deluge foam systems
  - Fire sprinklers (20 foot clear zone from foam system)
  - Fire extinguishers
  - Standpipes



- Mitigation recommendations
  - Alarm and Notification
    - Voice communication / Visual per ADA and in high ambient noise areas
  - Structural Fire Resistance
    - 3-hour fire rated with additional one-hour spray applied cover
  - Fire Separation
    - 12m between RCF - QTA
    - Expansion joint
  - Explosion Analysis
    - Vapor dispersion Analysis
    - Pipe chase explosion venting



ASET vs RSET Analysis

- Conclusions
  - Risk-informed analysis and design creates options where code-compliance or deterministic analysis alone note enough
  - Miami International Airport would not have been able to construct facility without risk-informed performance-based approach
  - Necessary to identify scenarios of concern, the impact of those events, the efficacy of FP systems installed, the reliability and redundancies needed, and impact on overall fire and life safety objectives
  - Data-driven exercise: input data, modeling (many scenarios), and evaluation

- Conclusions
  - Need to have all stakeholders on board – from the beginning through completion
  - Need agreement that 'zero risk' is not achievable, that 'meeting the code' does not mean 'absolute safety' and that engineering analysis, based on risk and reliability approach, can be successful

- Finally, don't forget about risk management…

- **Thank you for your attention! Any questions?**

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