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Shell Global Solutions

Management of Large LNG Hazards

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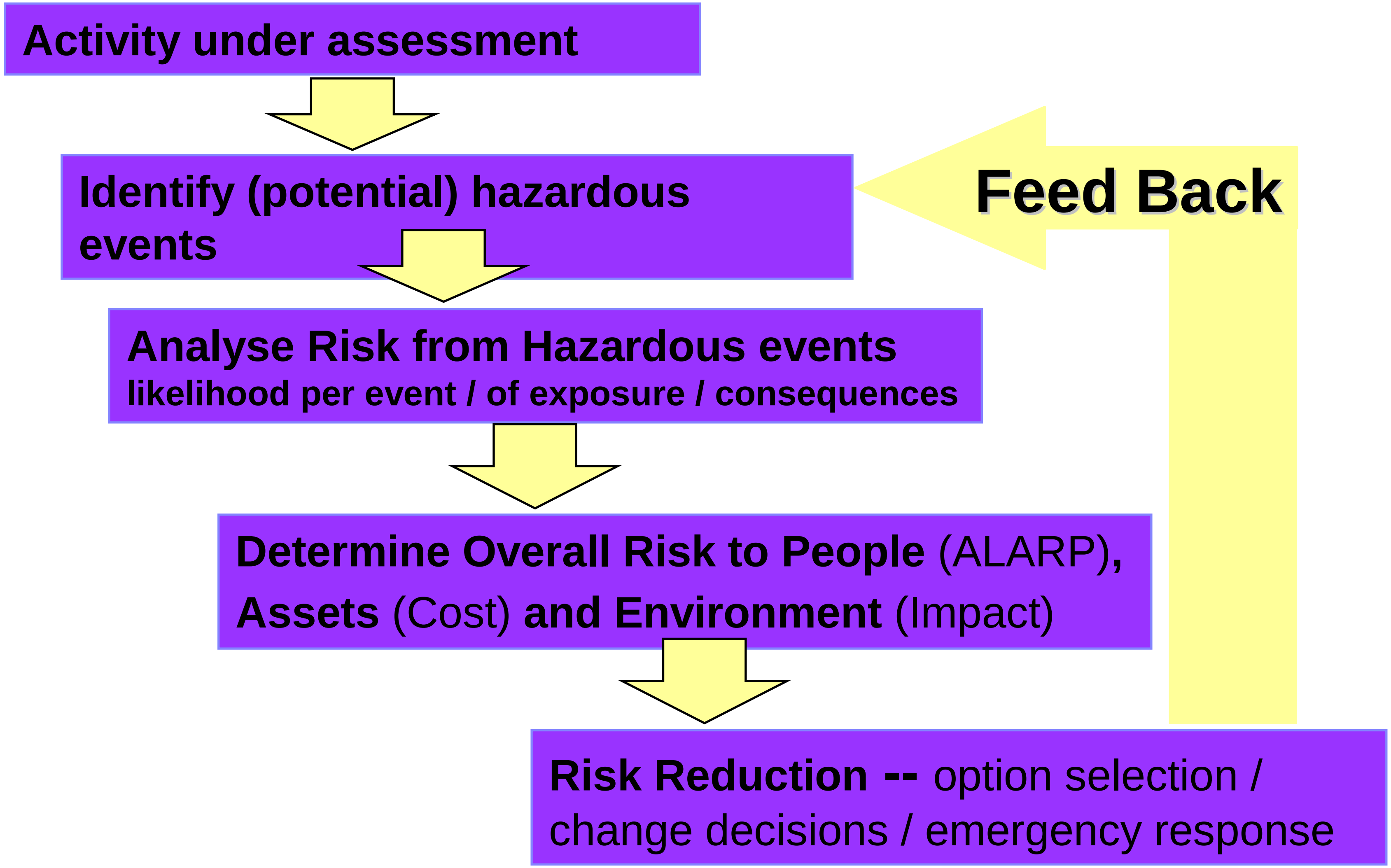
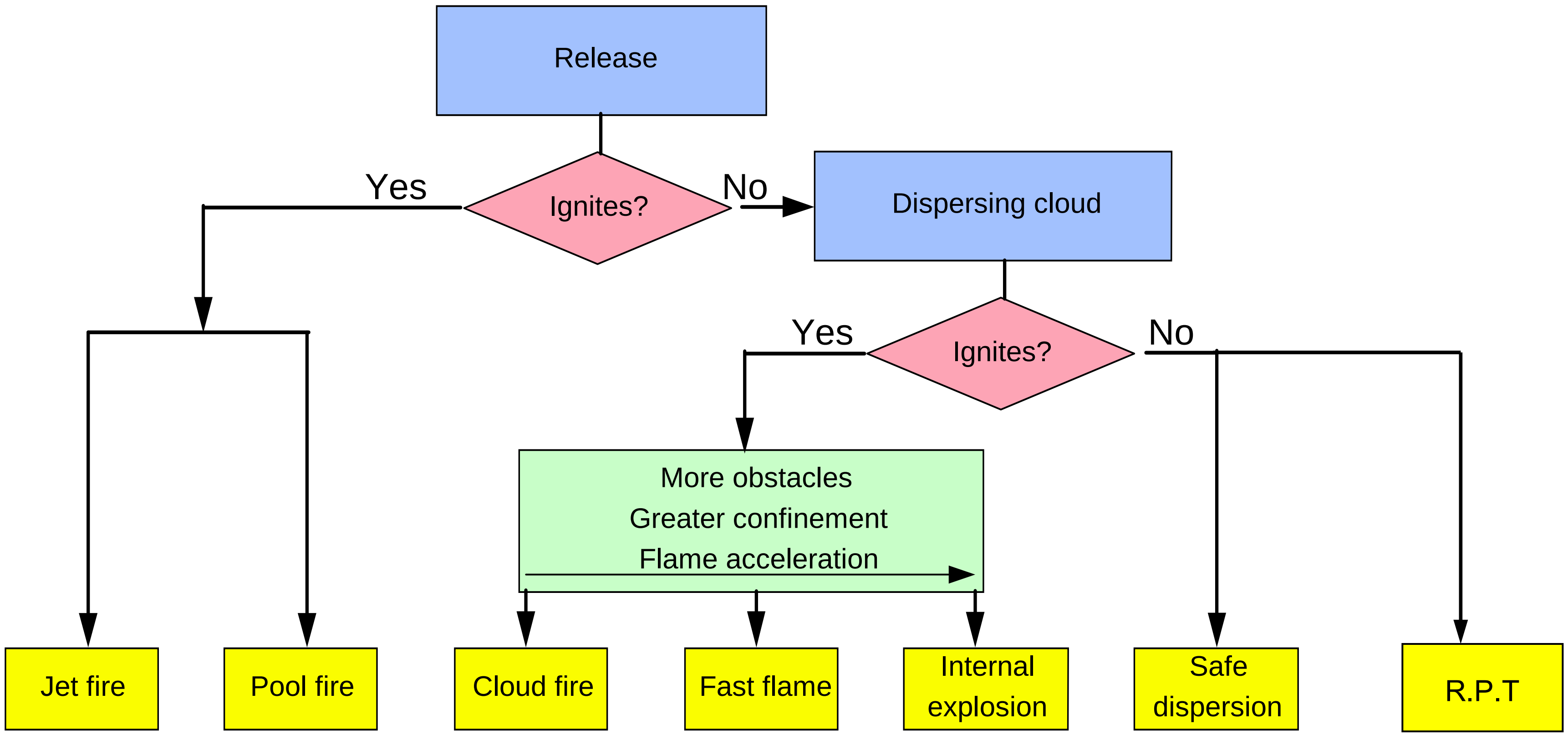
Outline

- HEMP
- Scenarios
- Pool spread and evaporation models
- Rapid Phase Transitions
- Pool fires
- Vapour Dispersion
- Vapour Cloud Explosions
- Conclusions

Hazard and Effect Management Process - HEMP



Major Hazard Scenarios. LNG.

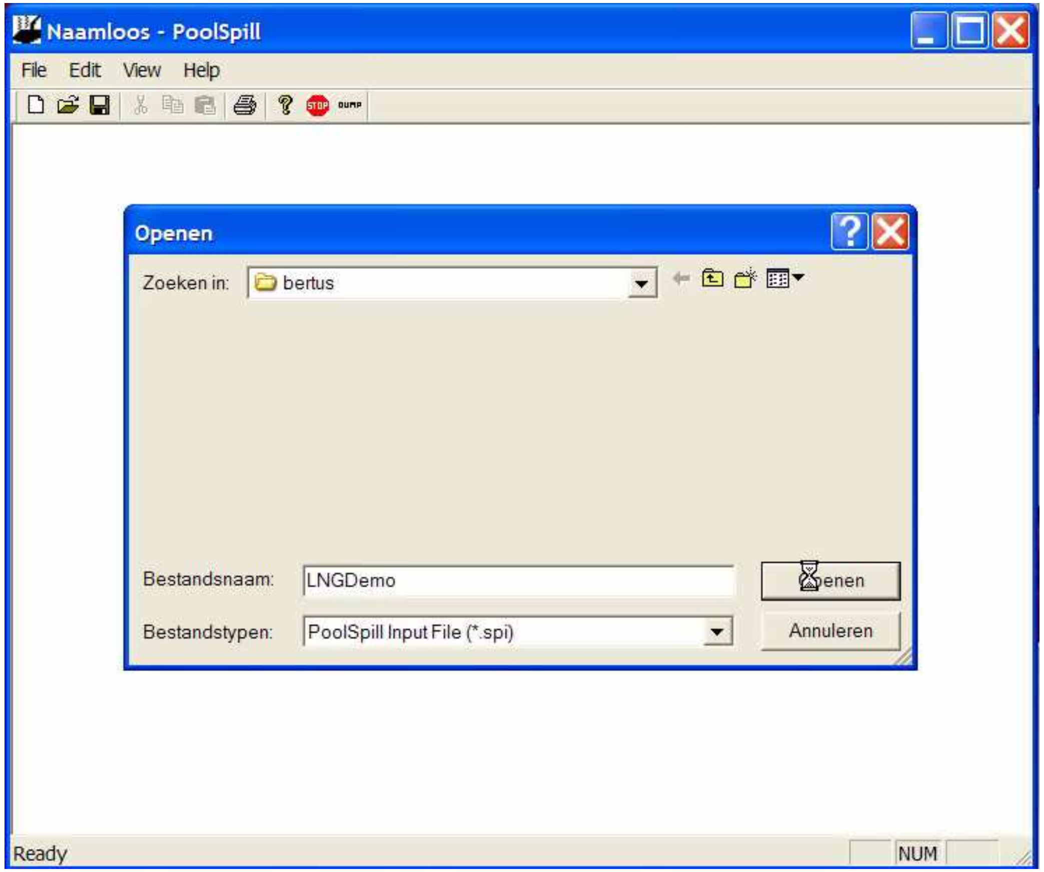


Pool Spread and Evaporation

- The source term for fire and explosion.
- Scope for improved physics and prediction.
- On land, substrate important after initial film-boiling phase. Porous substrates (sand or gravel) show greatly enhanced evaporation rates.
- On water, waves/currents can modify the evaporation rate, but not known exactly how. Some ice or hydrate may form in shallow water, eg Maplin Sands.

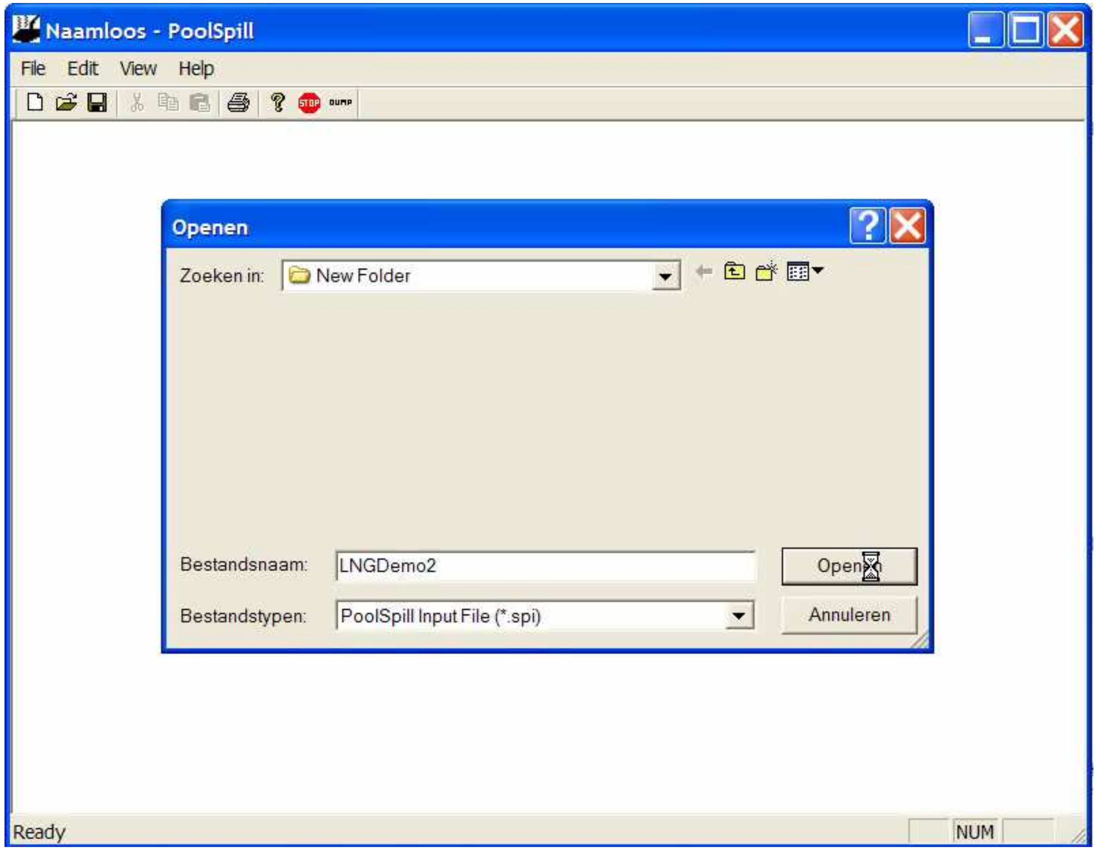
Model Demonstration of LNG pool spreading with wall

Spill of 0.1 m3/s LNG for 2s



Model Demonstration of LNG pool spreading with wall and tank

Spill of 0.1 m3/s LNG for 2s



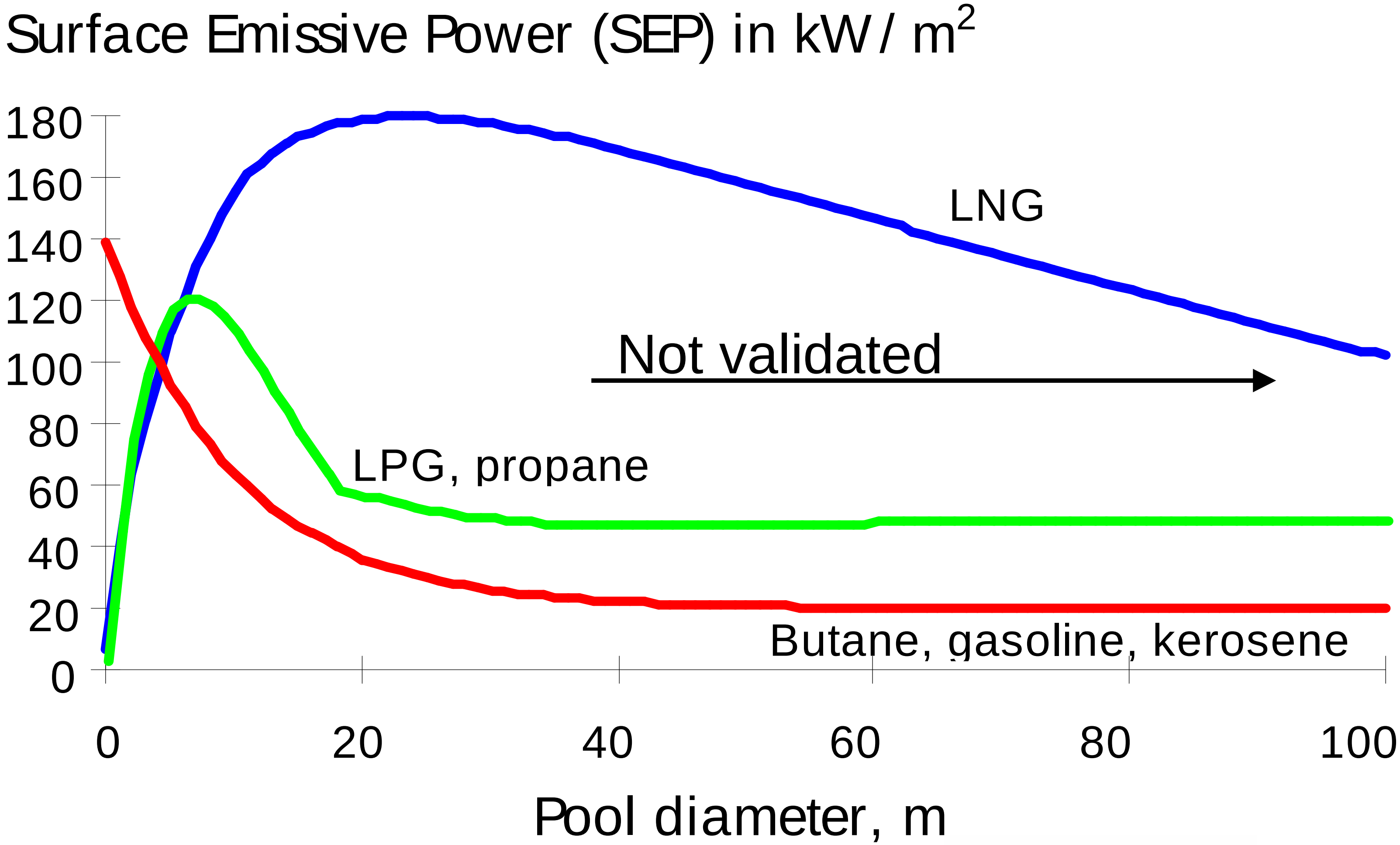
Rapid Phase Transitions RPTs

- Can occur, particularly if LNG has “aged”, and did occur at Maplin Sands.
- Spreading and evaporation become very different compared with gently spreading pools.
- RPTs create blast.
- Calculations suggest deformed hull but no rupture.
- E.g.150m^3 spill in 6m between FPSO and LNG carrier, blast energy on hull 60kJ/m^3.

Pool Fires

- 35m LNG pool fire.
- Montoir 1987

Model flame SEP versus pool diameter & fuel



LNG Pool Fires

- Thermal hazard depends on size and brightness.
- Average brightness [surface emissive power] peaks at about 180 kW/m^2
- Larger LNG pool fires expected to have lower SEP. The limit is 20kW/m^2 due to smoke.
- Flame height depends on upward momentum and buoyancy. Froude number scaling.
- Scaling predicts large LNG pools, say100m diameter, burn as “intermittant” fires. i.e. no change in burning regime. Does not become a “mass” fire (forest type fire).
- Steady burning rate on water around 0.22 $kg/m^2/s$.

LNG Vapour Dispersion

- Many models but many uncertainties remain for large spills.
- Uncertainties – roughness, strong temperature gradients over sea, humidity, heat transfer.
- Largest tests 100kg/s continuous, 20m^3 instantaneous.
- Releases over the sea. Unlikely that the flammable cloud becomes buoyant. LFL in visible cloud.
- Releases below sea. Plume becomes buoyant before LFL.
- CFD modelling and Random Walk modelling (DICE) – ones to watch.

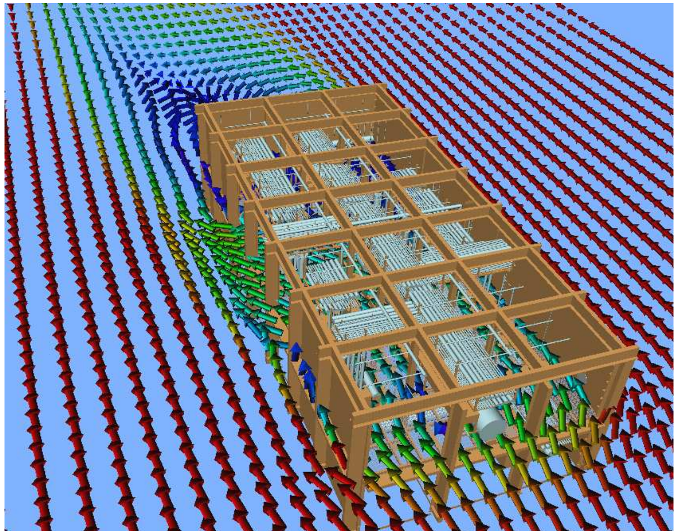
DICE (Dispersion In Congested Environments)

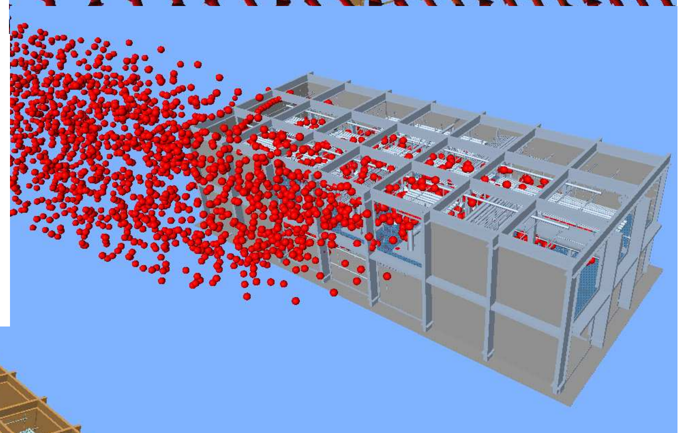
- Model dispersion using particle based random walk model
- Particle velocity =

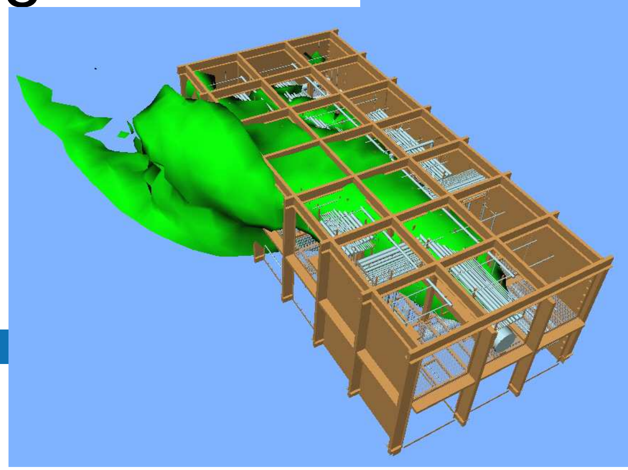
  background flow velocity +

  semi-random turbulent component +

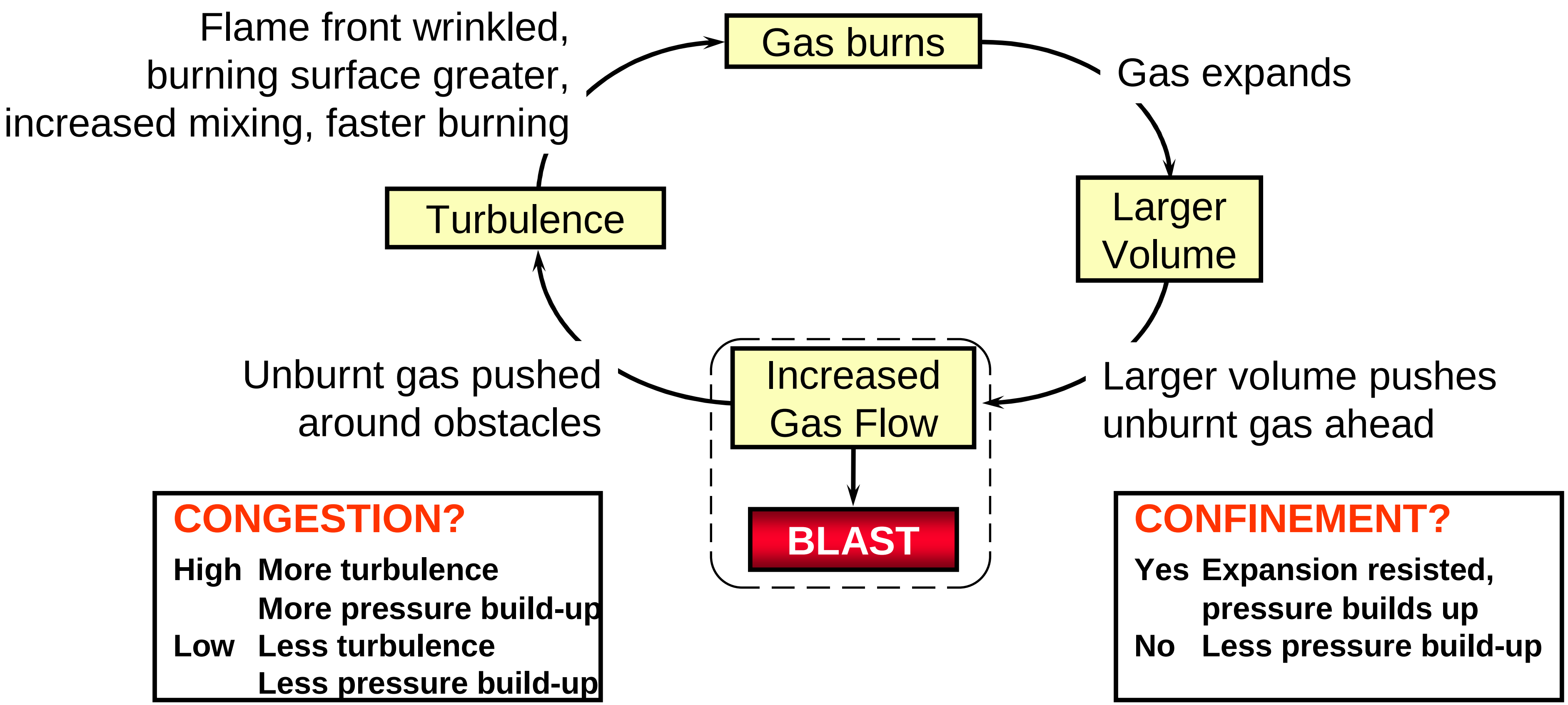
  velocity due to jet release momentum
- Calculate trajectories of 1000s of particles and determine gas concentration







LNG vapour cloud explosion - Schelkin feedback loop

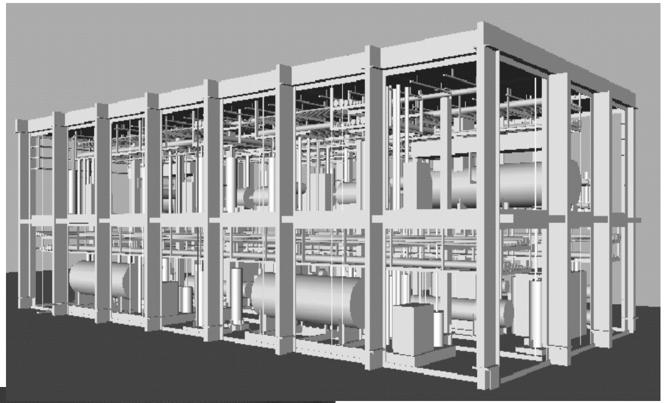


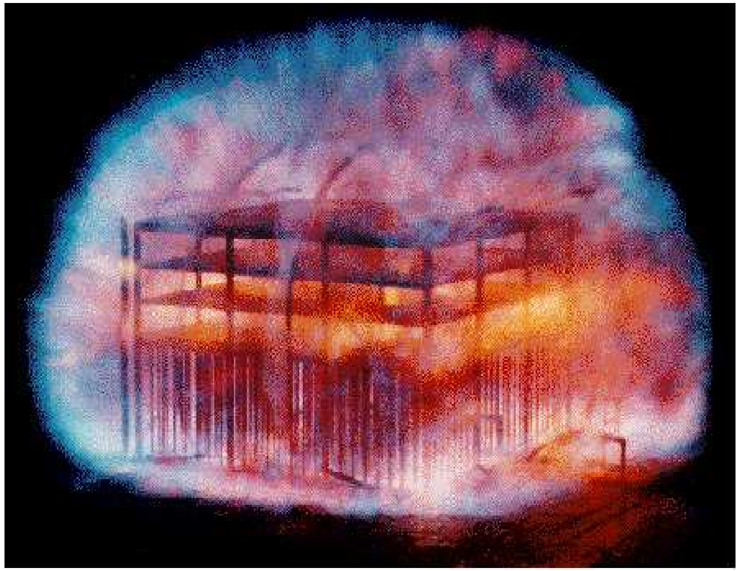
The size of the flammable cloud or the congestion determines the explosion severity, whichever is the smaller

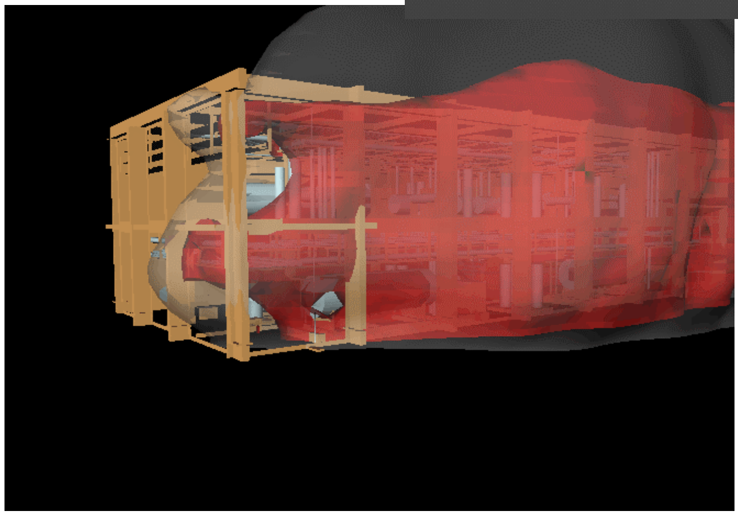
Shell's Explosion models

Overpressure and impulse prediction

CAM, SCOPE, EXSIM

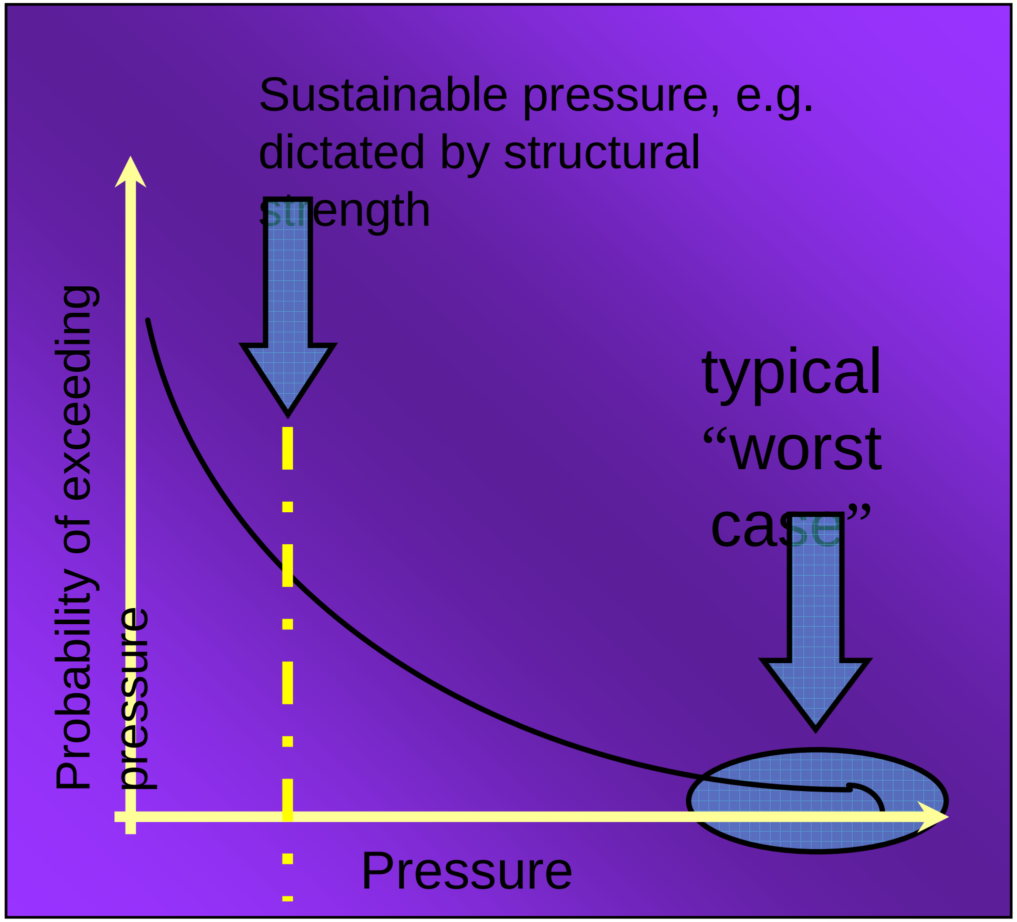




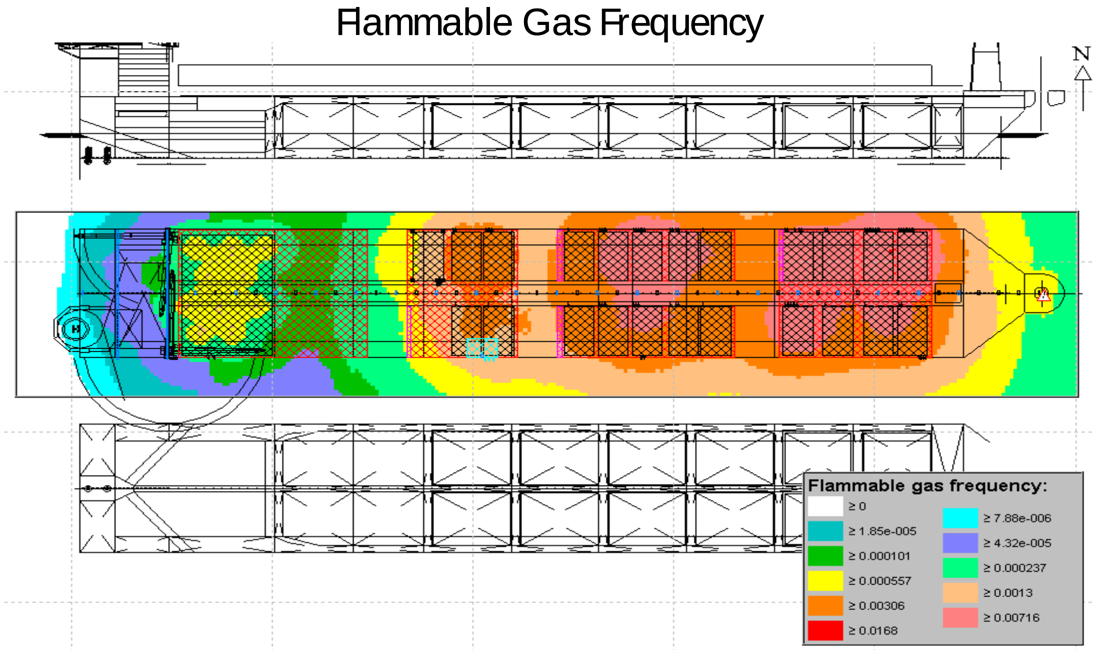


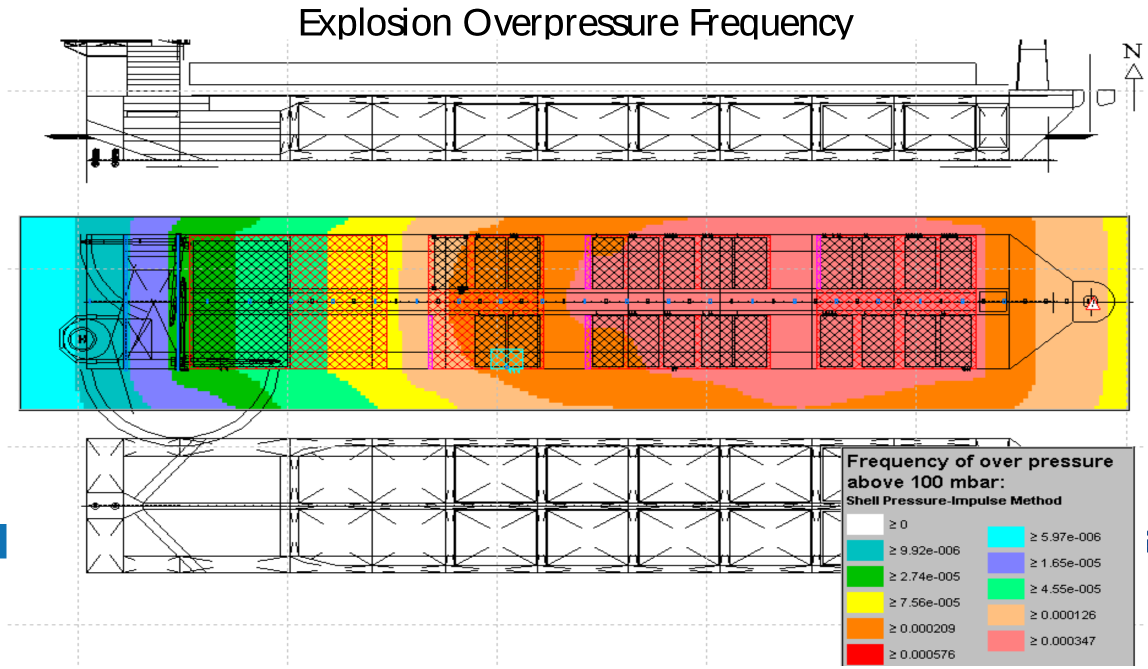
Probabilistic approach - 'Exceedance'

- Method for determining the probability (frequency) of exceeding a certain overpressure (and impulse) at a given location.

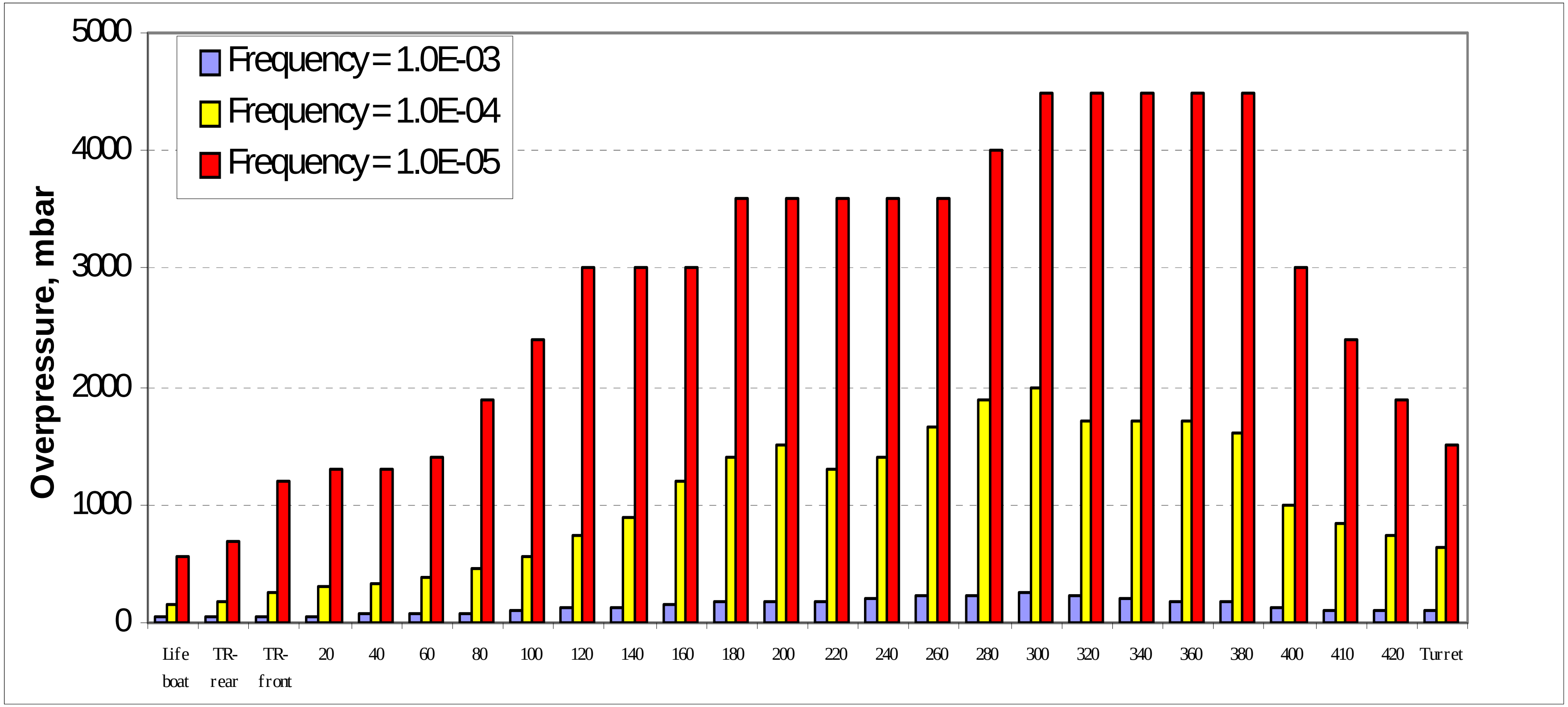


Flammable gas mapping and explosion exceedance applied to a Floating LNG concept



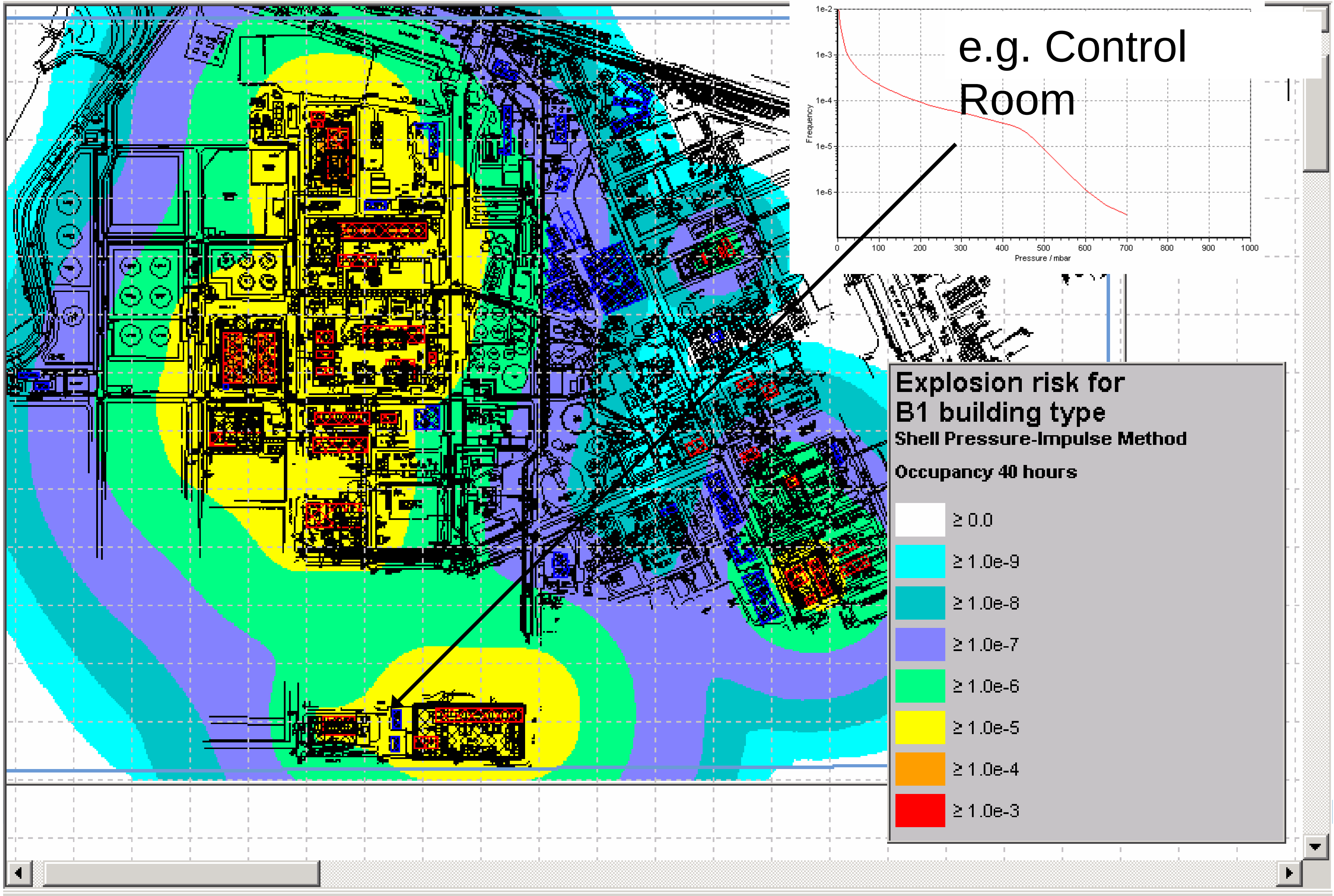


Explosion Overpressure Exceedance over the deck of a Floating LNG ship.



Experimental study of the critical gap to limit explosion severity between process units

Example of explosion exceedance for safe placing of trailers on a plant



Conclusions

- HEMP studies can account for major LNG hazards.
- A hierarchy of modelling tools can be brought to bear with increasing accuracy as the safety criticality increases.
- But extrapolation to large scale places large demands on the physics and experimental validation is preferably required.
- A few areas for further study - Pool spreading and evaporation, effect of substrates, the burning regime for large pool fires, vapour cloud explosion sub-grid modelling.