Risk-Based Approach to Building Designs and Decision Making

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Key Items

- The 'Bunker Mentality'
- Concepts
  - Building Damage Levels
  - Occupant Vulnerability (OV)
  - Risk – Individual and Societal
- Risk Based Resource Allocation
  - Explosion Risk
  - Toxic Risk (Shelter-In-Place)
- Master Planning
- Optimal Building Location/Real Estate Cost

The 'Bunker Mentality'

- 'Bunker' here refers to a very strong building
- Bunkers are massive buildings that are typically orders of magnitude more robust than conventional buildings
- These are sometimes designed for the 'Maximum Credible Event' or MCE (API 752)
  - Feasible only if credible event is small enough
- Likelihood of events is often ignored

Credible Event?

cred·i·ble

/ˈkredəb(ə)l/

adjective

able to be believed; convincing.

"few people found his story credible"

synonyms: believable, plausible, tenable, able to hold water, conceivable, likely, probable, possible, feasible, reasonable, with a ring of truth, persuasive

"only one of the so-called witnesses could provide a credible story"

- capable of persuading people that something will happen or be successful.

  "a credible threat"

  synonyms: believable, plausible, tenable, able to hold water, conceivable, likely, probable, possible, feasible, reasonable, with a ring of truth, persuasive

  "only one of the so-called witnesses could provide a credible story"

The ‘Bunker Mentality’

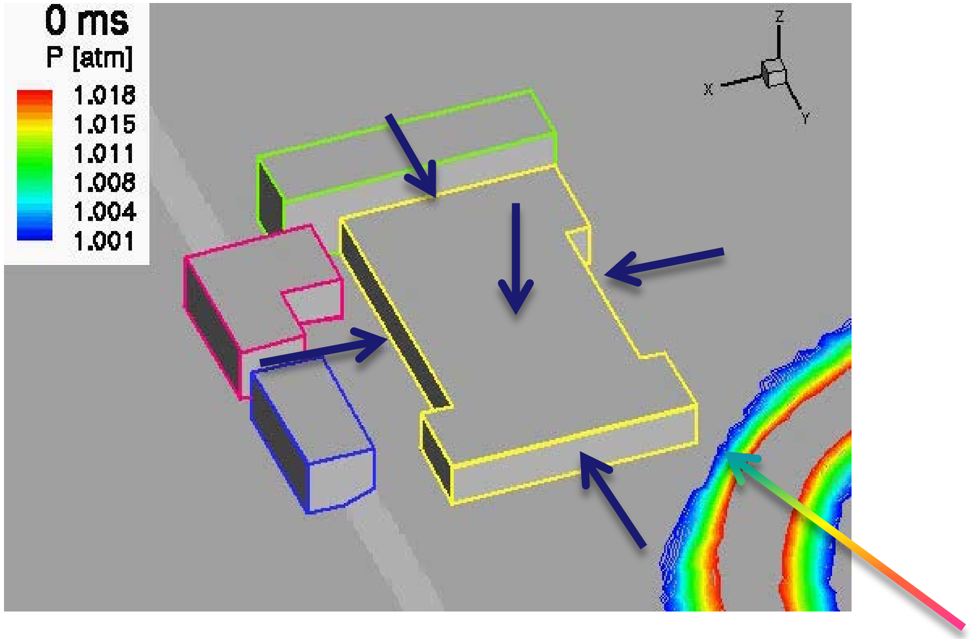
“Everything is cheap if you are not paying for it….”

???

- How can we avoid ‘Bunkers’ and still ensure safety?
- Likelihood of events:
  - Should a designer ignore events with low frequency?
  - But what if multiple events have a low frequency?
  - What if certain events have a Low Frequency but very high impact/consequence?
- Larger Question: How do I determine my design basis?

Blast Loading of Buildings

Direction of blast



Direction of blast

Blast Structural Damage

Front

Side

Back

Understanding Building Damage Levels (BDL) and Occupant Vulnerability (OV)

Building Damage Levels

BDL 1 - Minor

BDL 2 - Moderate

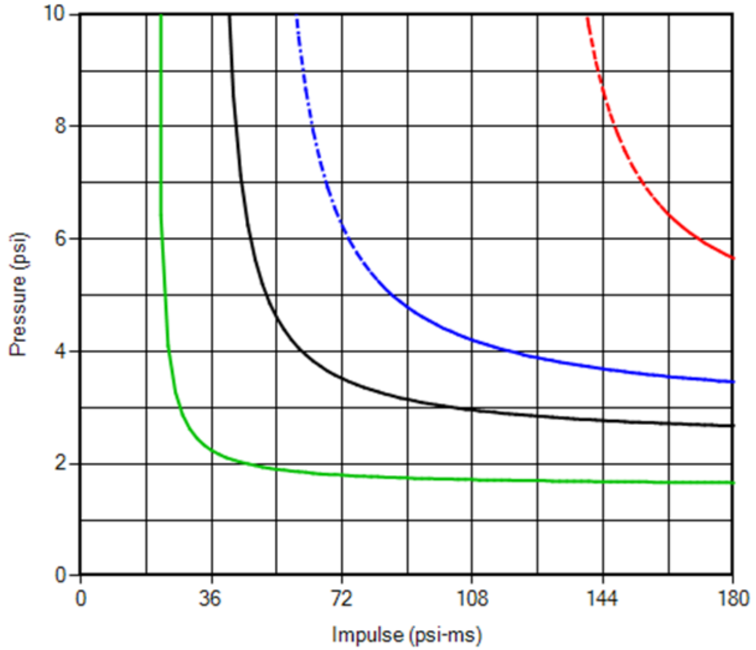
BDL 2.5 - Heavy

BDL 3
Major

BDL 4
Collapse

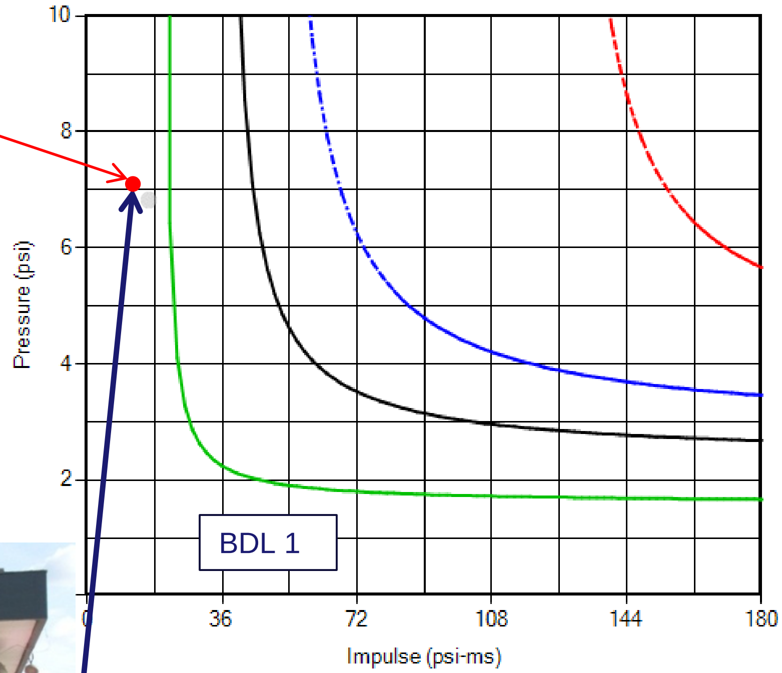
Pressure-Impulse (P-i) Curves

- What are Pressure-Impulse (P-i) Curves?
  - A graphical way to assess Building Damage Level as a function of Pressure and Impulse of blast load
  - P-i Curves are characteristic of building or structural component.



BDL 1 - *OV = .01%*

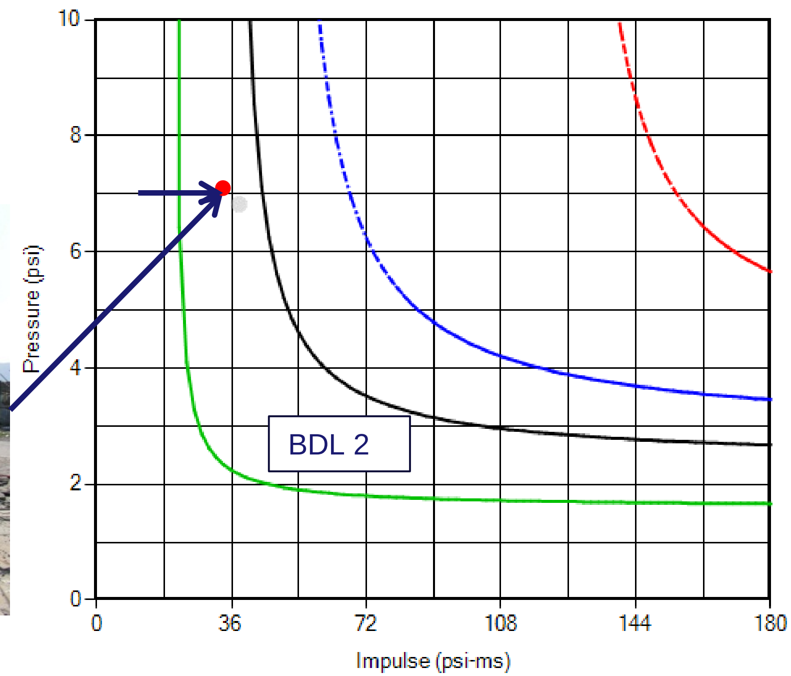
Blast Load



Blast Load is to the left or below the GREEN Curve – Means BDL =1

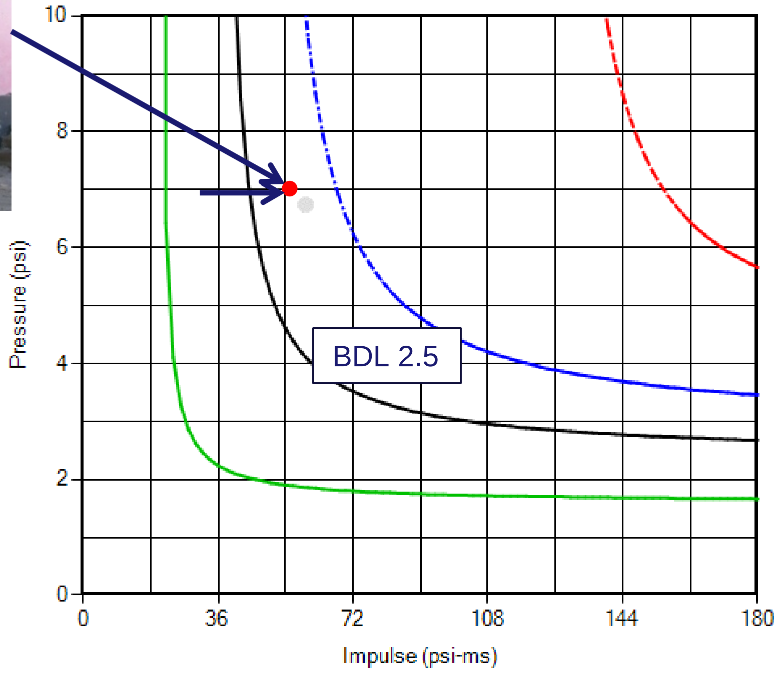
OV = Occupant Vulnerability or Likelihood of Fatality

BDL 2 - *OV = .03%*



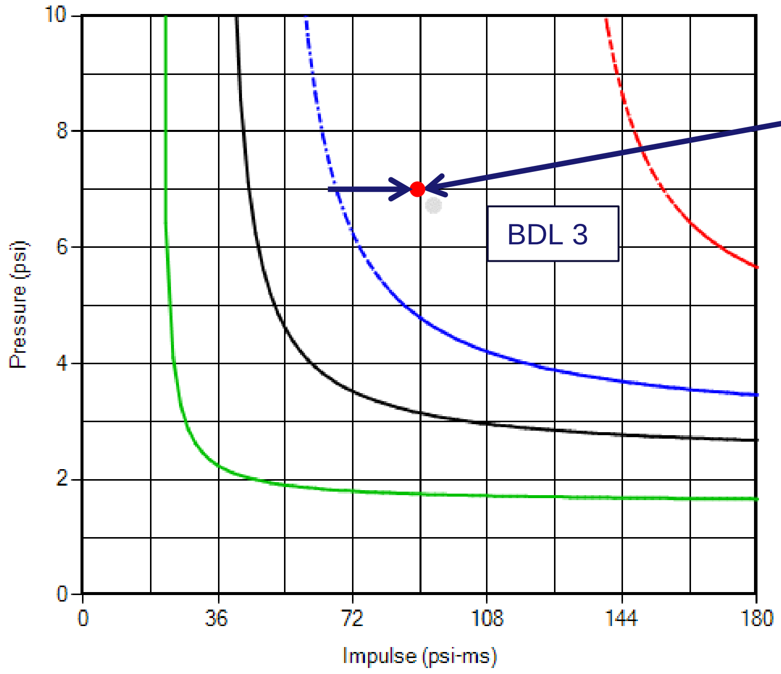
OV = Occupant Vulnerability or Likelihood of Fatality

BDL 2.5 - *OV = 3%*

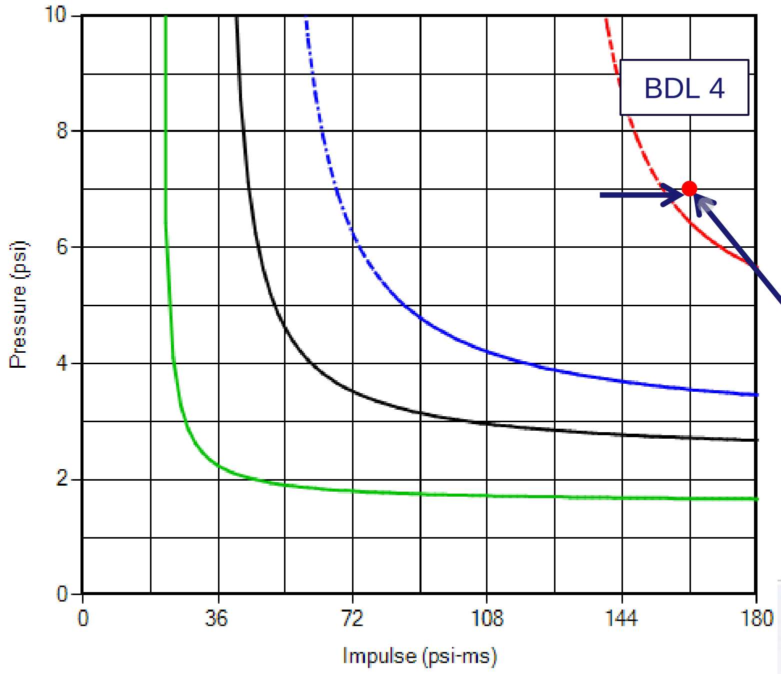


OV = Occupant Vulnerability or Likelihood of Fatality

BDL 3 - *OV = 30%*



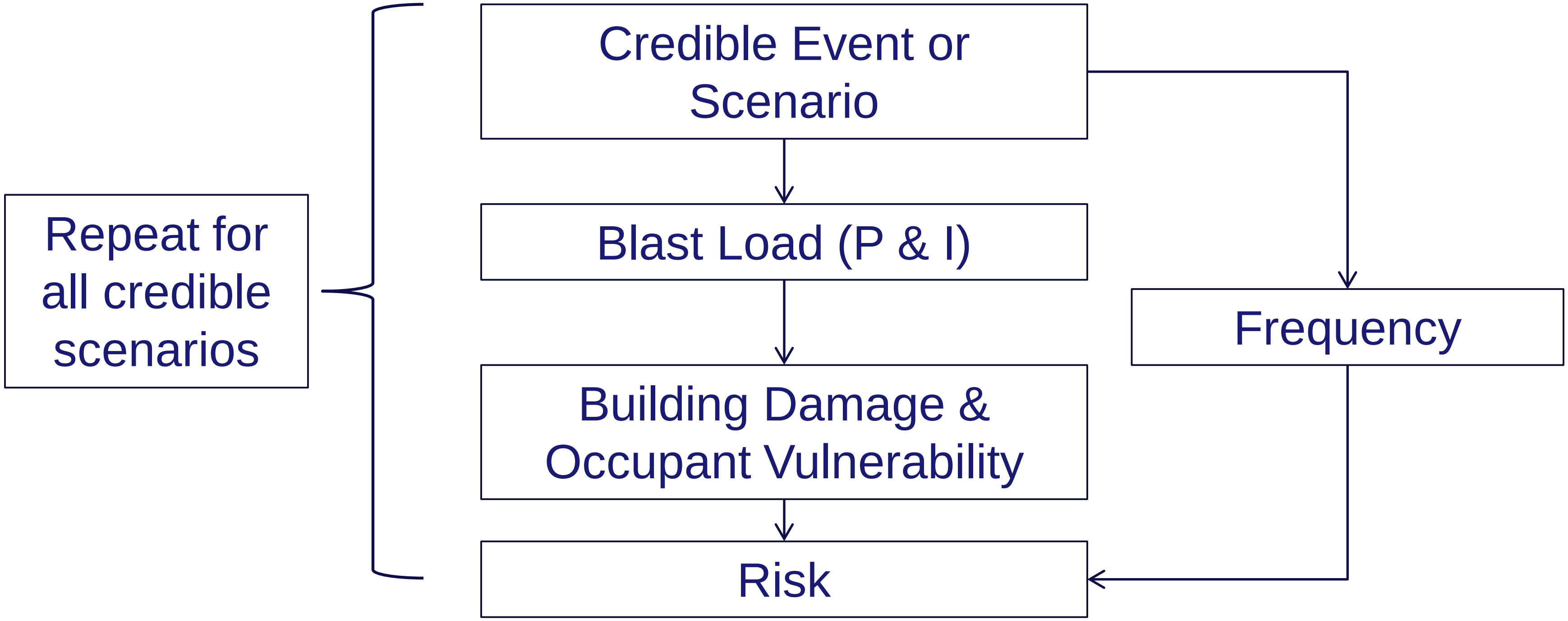
BDL 4 - *OV = 90%*



Building Individual Risk (BIR)

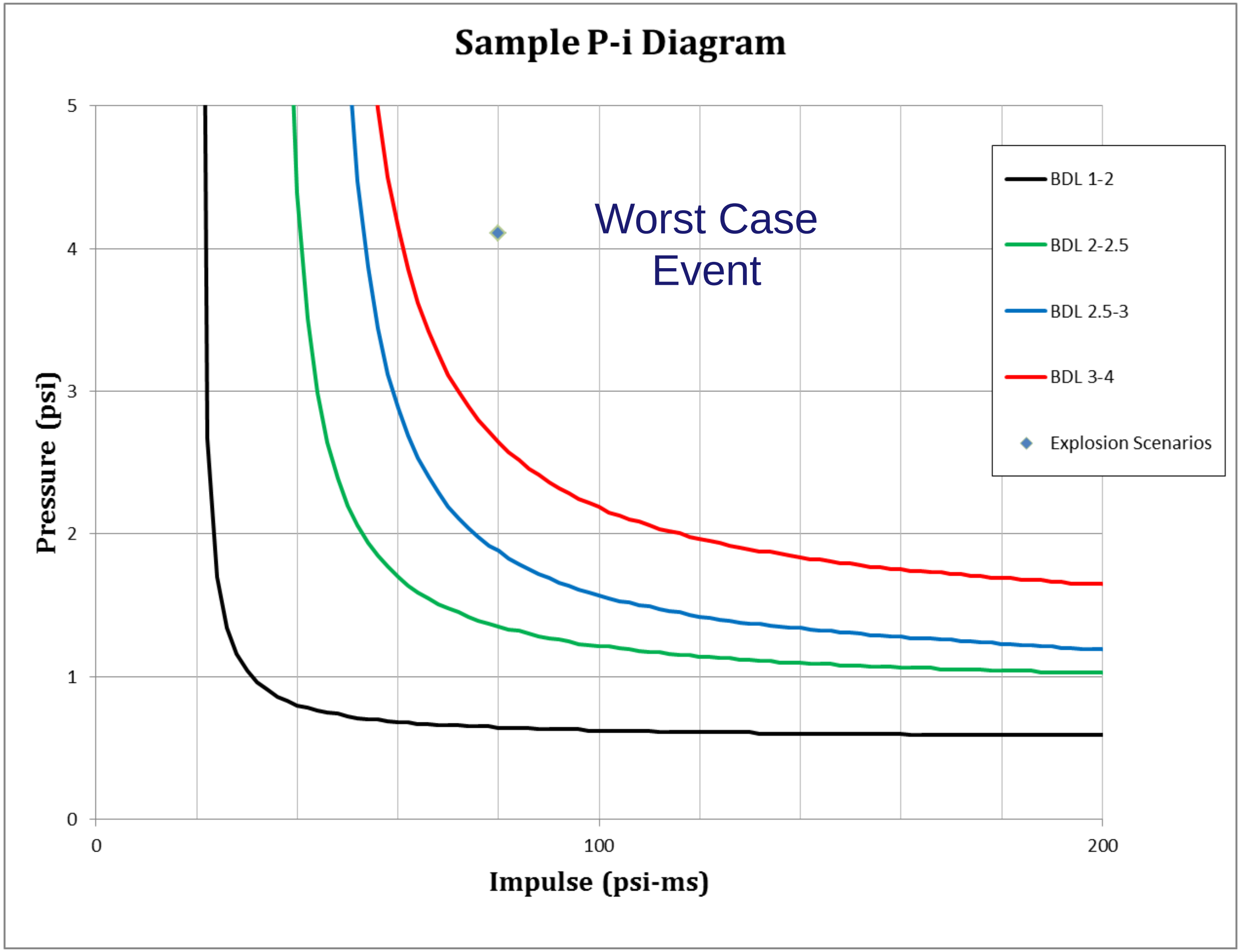
- BIR (fatalities/year) = OV x Frequency
  - OV (Number of Fatalities per event) – Based on Blast load, BDL, population distribution, type of structure, etc.
  - Frequency (Events/year) - Based on failure rate, wind direction, meteorological conditions, probability of ignition, etc.
- Societal Risk = OV x Occupancy x Frequency

Summary

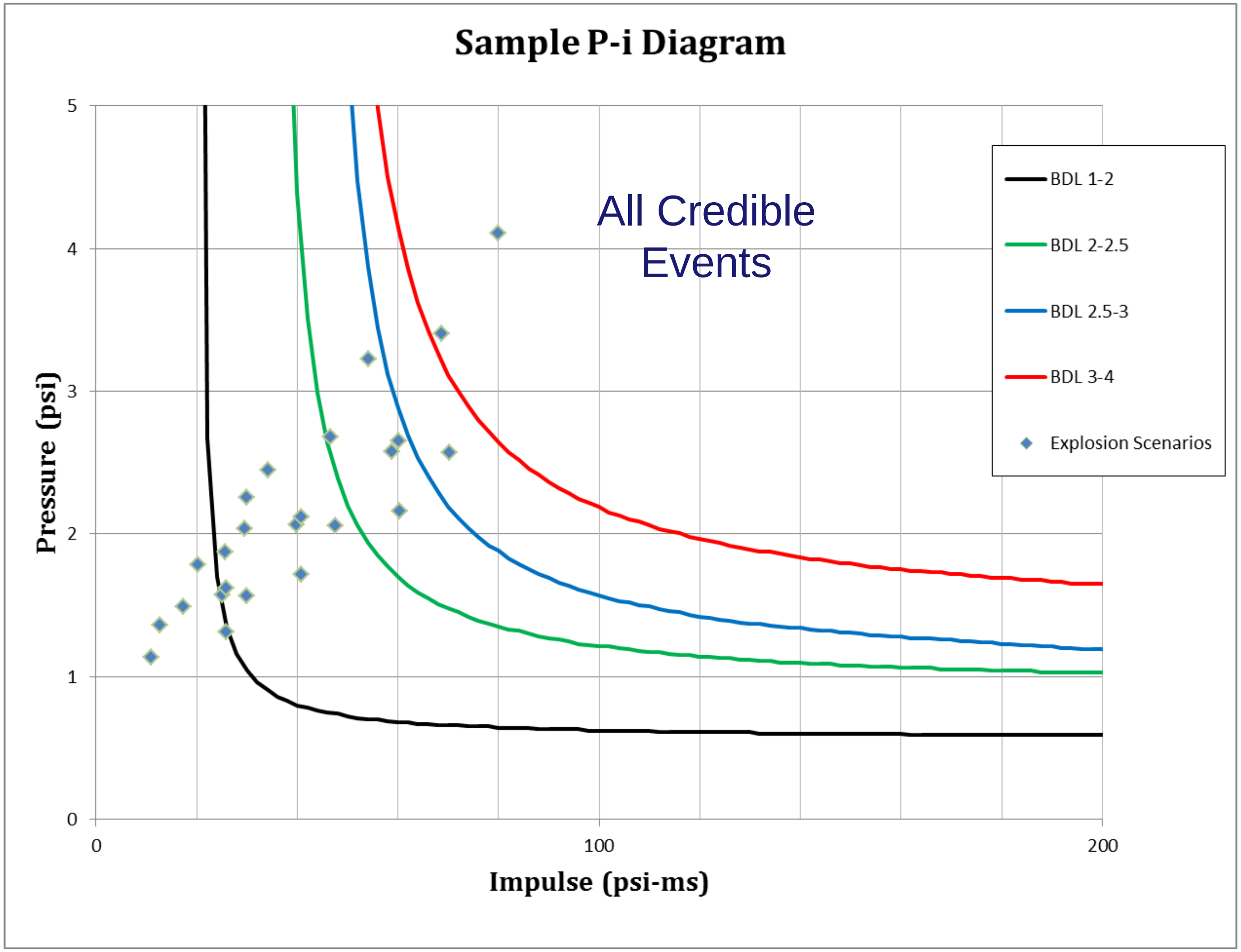


$$\text{Societal Explosion Risk} = \sum \text{Risk}_{\text{scenario}}$$

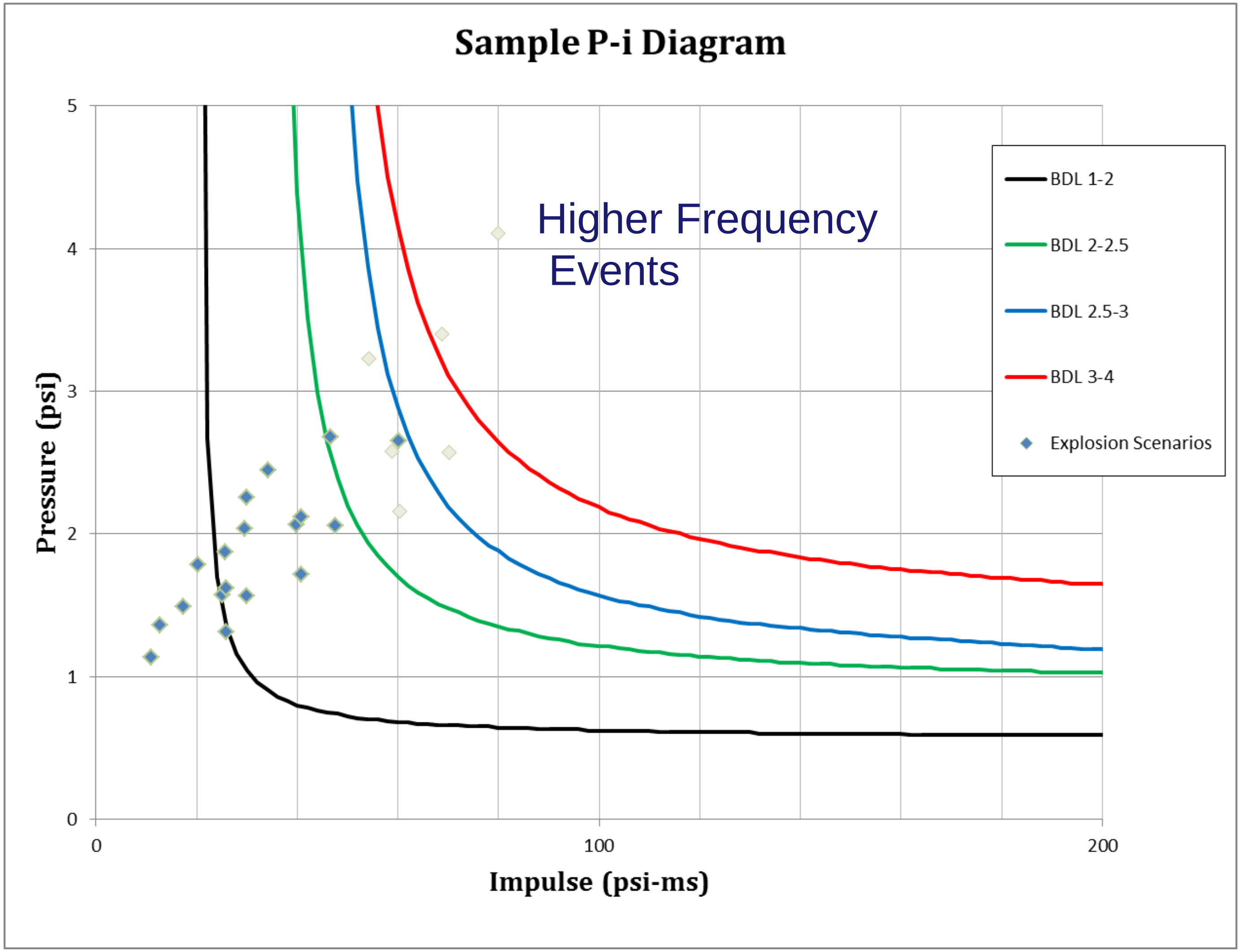
Design Explosion Cases



Design Explosion Cases



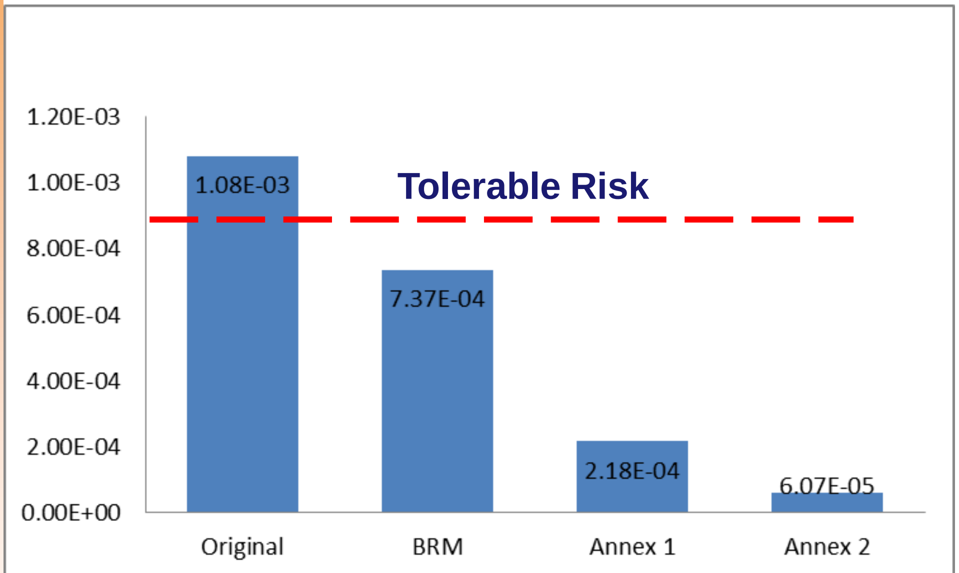
Design Explosion Cases

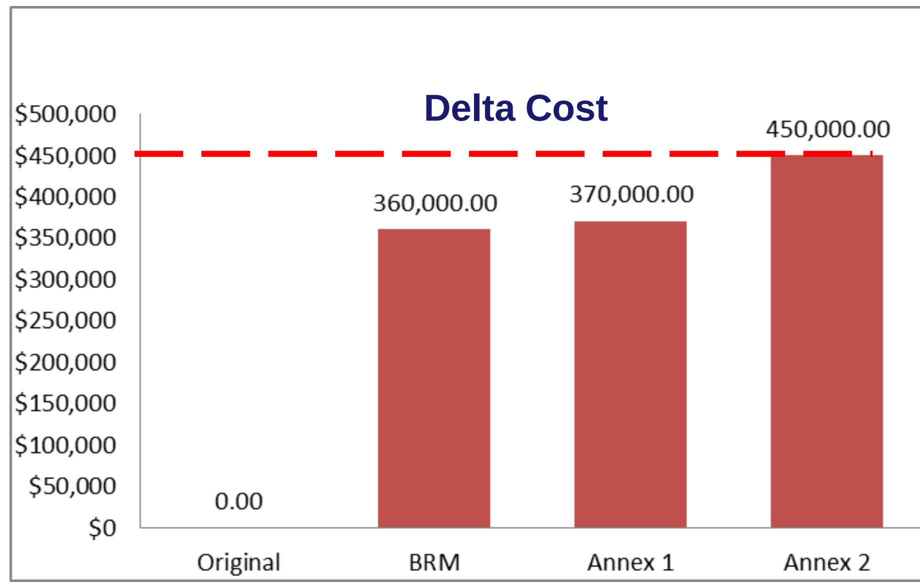


Cumulative Risk - Example

Explosion Scenario	BDL	OV	Frequency	Risk
1	2	0.00035	1.50E-06	5.25E-10
2	4	0.78	2.00E-09	1.56E-09
3	2	0.00035	3.00E-05	1.05E-08
4	1	0.0001	1.00E-04	1.00E-08
n	2.5	0.005	6.00E-08	3.00E-10
Σ Risk ***Note: It is not uncommon to have n > 5,000***				**2.29E-08 Fatalities/year Or 23 fatalities in a billion years**

Evaluate Building Options

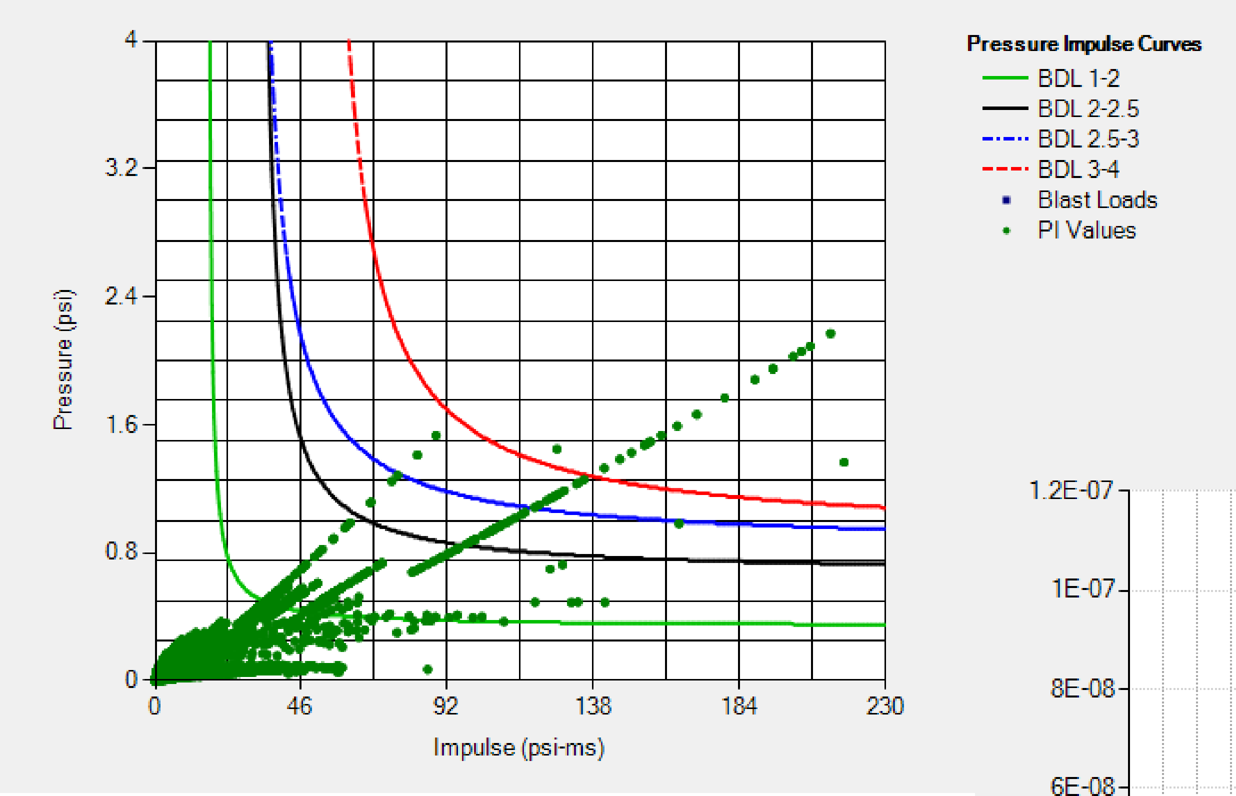




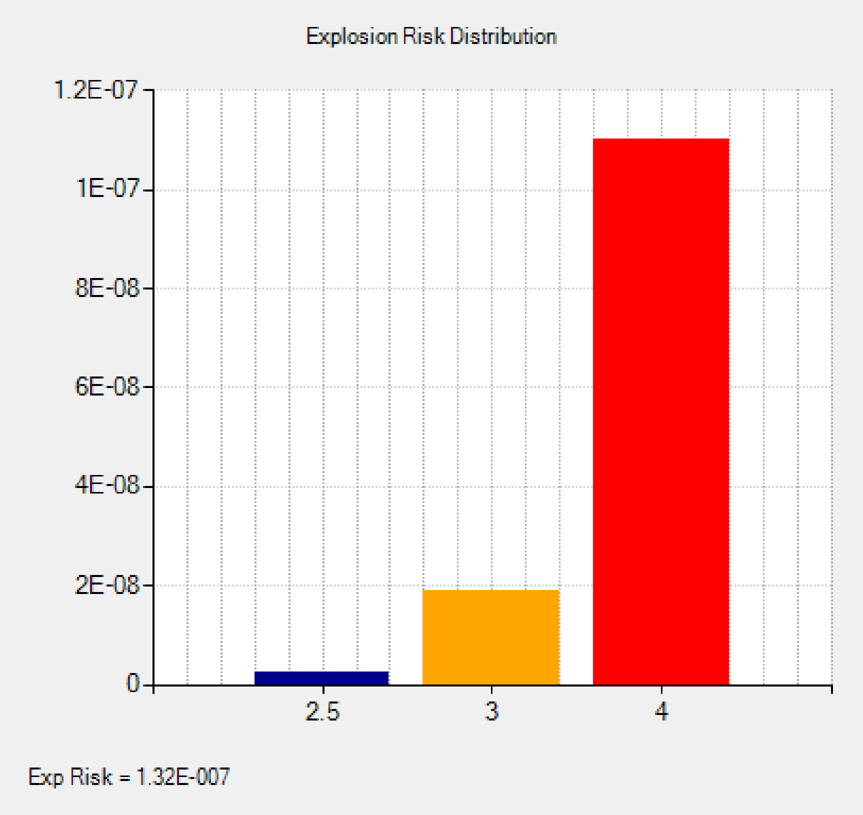
HSE/PSM Teams Involved

Project Team

Example



Risk Distribution

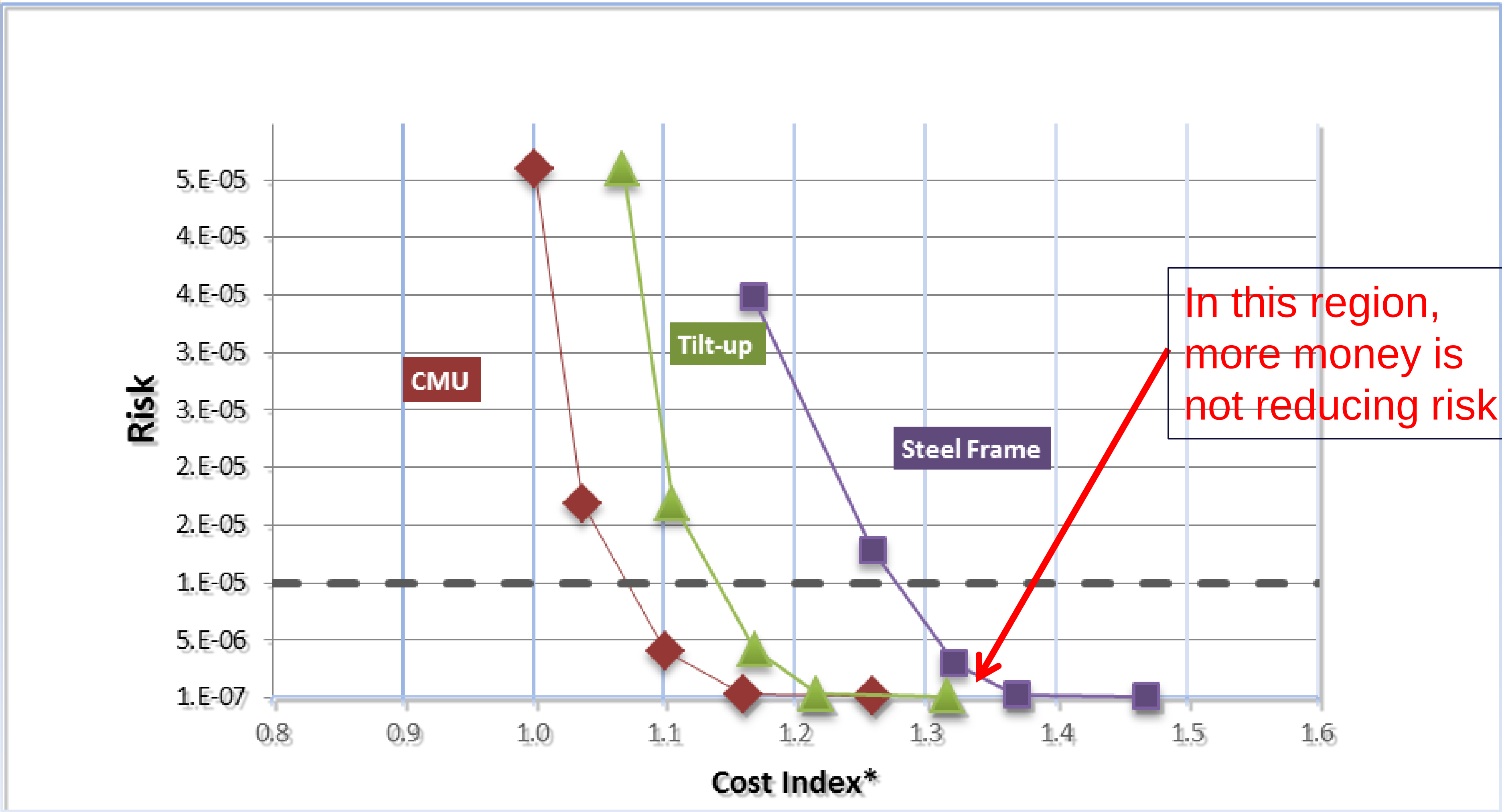


Edwards v. National Coal Board in 1949

ALARP Principle has been enshrined in the UK case law

Reasonably practicable is a narrower term than 'physically possible' and implies that a computation must be made... in which the quantum of risk is placed in one scale and the sacrifice involved in the measures necessary for averting the risk (whether in time, trouble or money) is placed in the other and that, if it be shown that there is a great disproportion between them – the risk being insignificant in relation to the sacrifice – the person upon whom the obligation is imposed discharges the onus which is upon him.

Risk vs Cost: Various Building Types

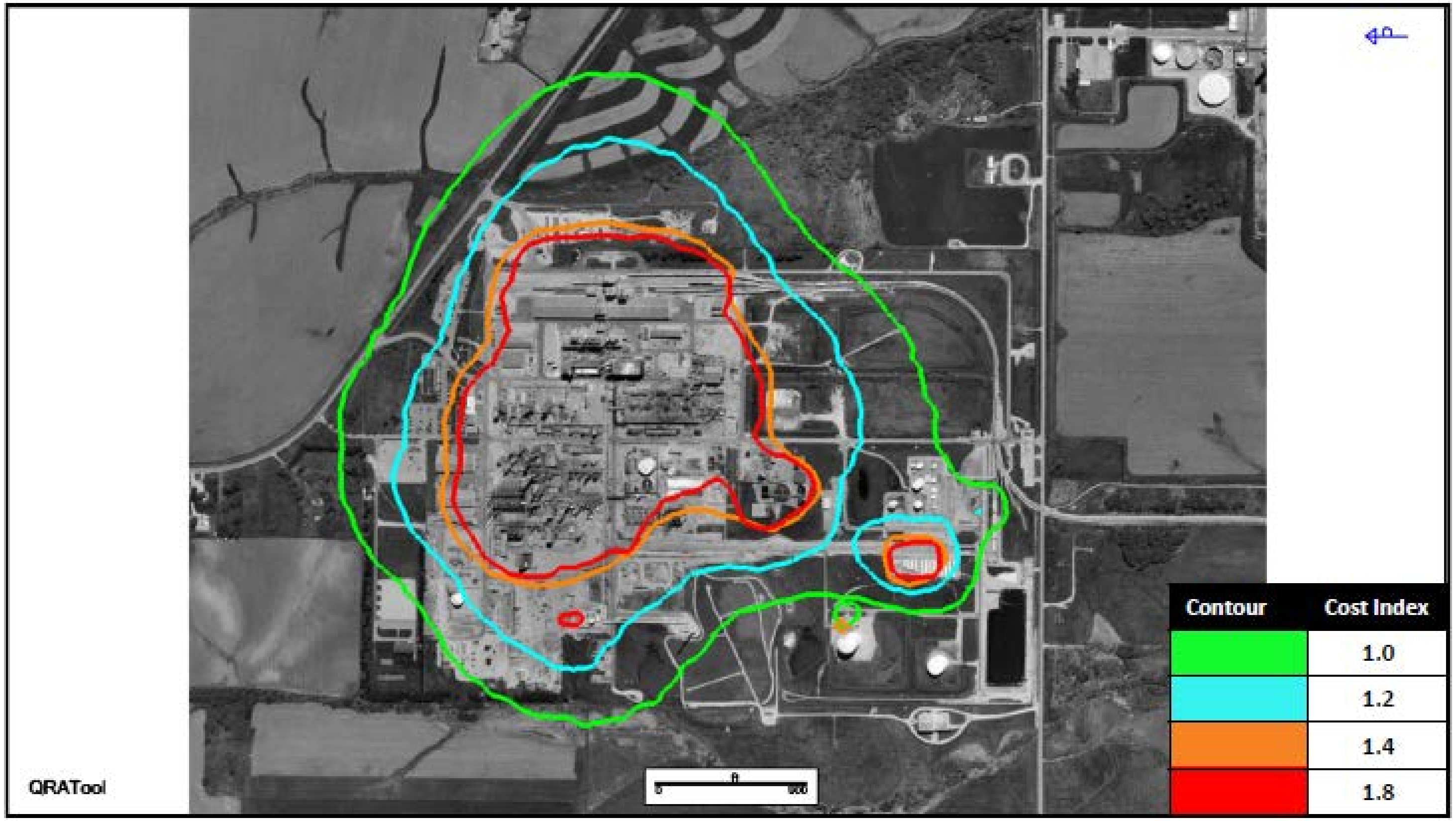


Master Planning

Building	Explosion Risk	Building Risk/Total Risk	Unit Cost/Building
Administration Building	4.0E-07	0.3%	29%
Control Room	5.0E-06	3.7%	20%
Laboratory	2.0E-05	14.8%	15%
MCC 1	3.0E-05	22.2%	10%
MCC 2	6.0E-05	44.3%	10%
Maintenance	2.0E-05	14.8%	16%
Total	**1.4E-04**	**100.0%**	**100%**

Optimal Location and Real Estate Planning

New Staff Office Building
Cost Contour for 1E-6 BIR



Toxic SIP – Risk Approach

- Multiple toxic release locations (one or more types of toxics)
- Several possible wind directions with different probabilities
- Angle of Release: Several Possibilities
- Building has different leakage characteristics at different wind speeds

For Each Release…

- Estimate Toxic Concentration Outside the building for each scenario
- Estimate Air Change Rate (ACH) for the scenario (Based on Tracer Gas Test/Blower Door Test for buildings)
- Based on ACH for the scenario, estimate inside concentration for the building
- Based on toxic concentration, estimate OV using Probits. That’s your consequence!
- Estimate Risk = Frequency x Consequence
- If the risk is acceptable, the building may be an acceptable SIP

Decision Process

- ✓ Determine if alternative designs effectively reduce risk
- ✓ Estimate cost/Δ_{risk} for each alternative
- ✓ Choose lowest cost/Δ_{risk} within budget
- ✓ Proceed with design

Conclusions

- Expensive building designs can be avoided without compromising on safety
- When thousands of scenarios are postulated, a Risk Based Approach can be effectively used to optimize resources and maximize safety
- A Risk Based Approach can be used in:
  - Designing a building or
  - Determining the most optimal location on the facility
- This conceptual framework can be used for various types of hazards – Explosion, Toxic, Fire etc.

Questions?

Thank You