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Back to Basics:
Risk Matrices & ALARP

Glen Wilkinson

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Session Overview

Has the Risk Matrix approach been stretched too far ?

- **Topics covered:**
  - **Risk Management Basics**
  - Risk Matrices
  - Arguing ALARP
  - Conclusions

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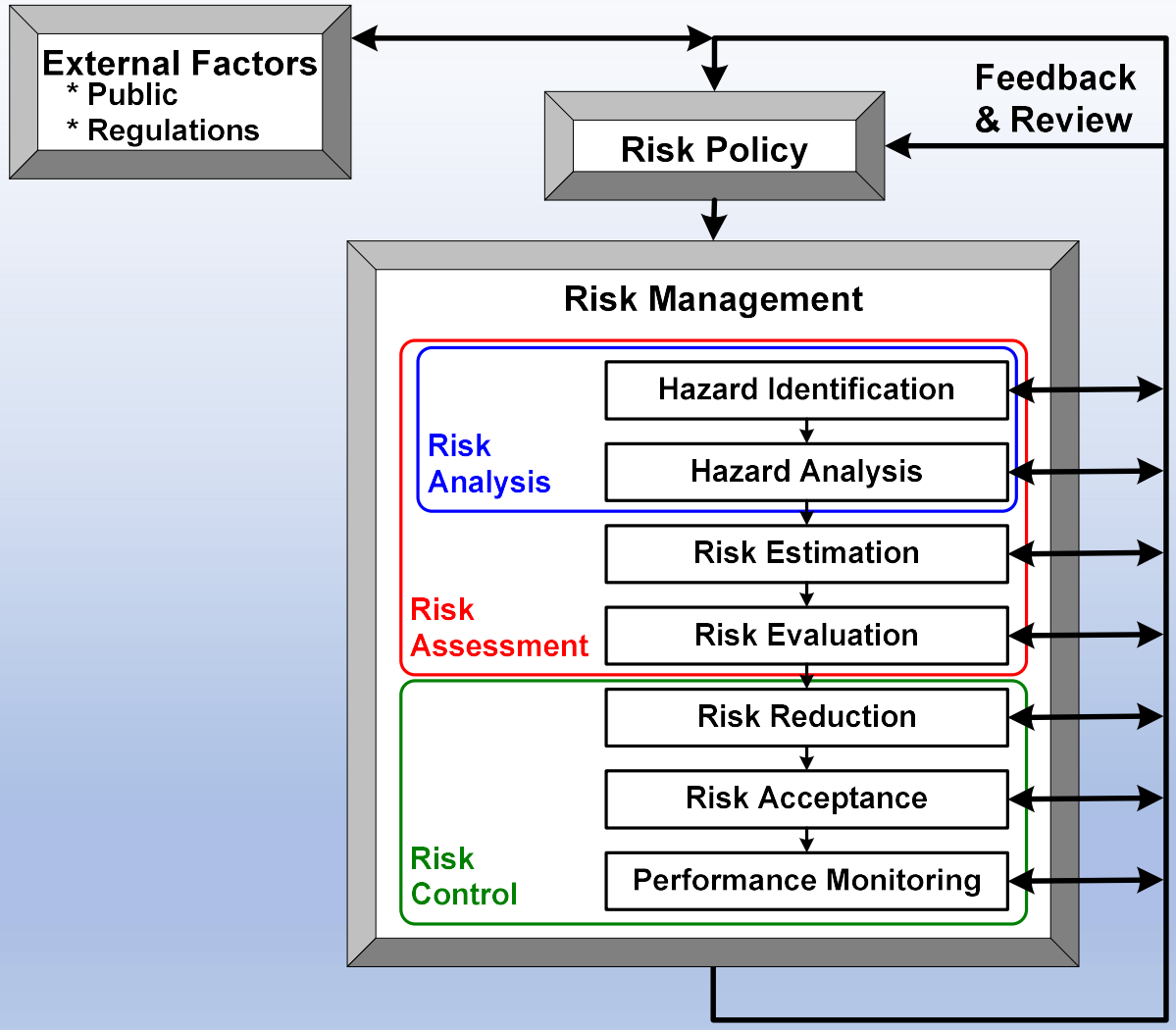
UK MoD Risk Management Process (POSMS)



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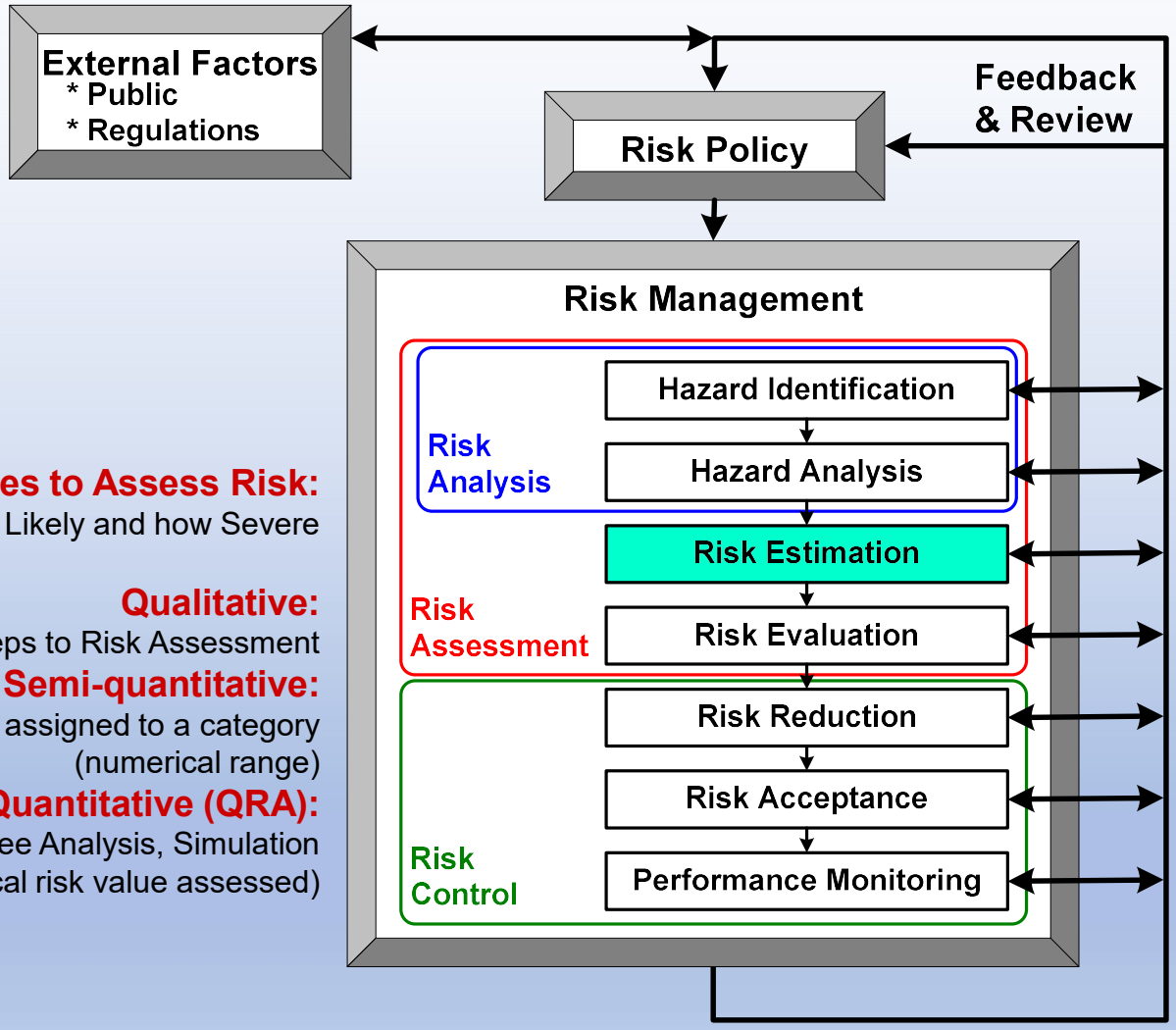

Techniques to Assess Risk:
How Likely and how Severe

Qualitative:
E.g. HSE 5 Steps to Risk Assessment

Semi-quantitative:
E.g. Risk subjectively assigned to a category (numerical range)

Quantitative (QRA):
E.g. Fault Tree / Event Tree Analysis, Simulation (absolute numerical risk value assessed)

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What is a Risk Matrix?

- A Framework for Ranking/Screening “Single Risks” for prioritisation

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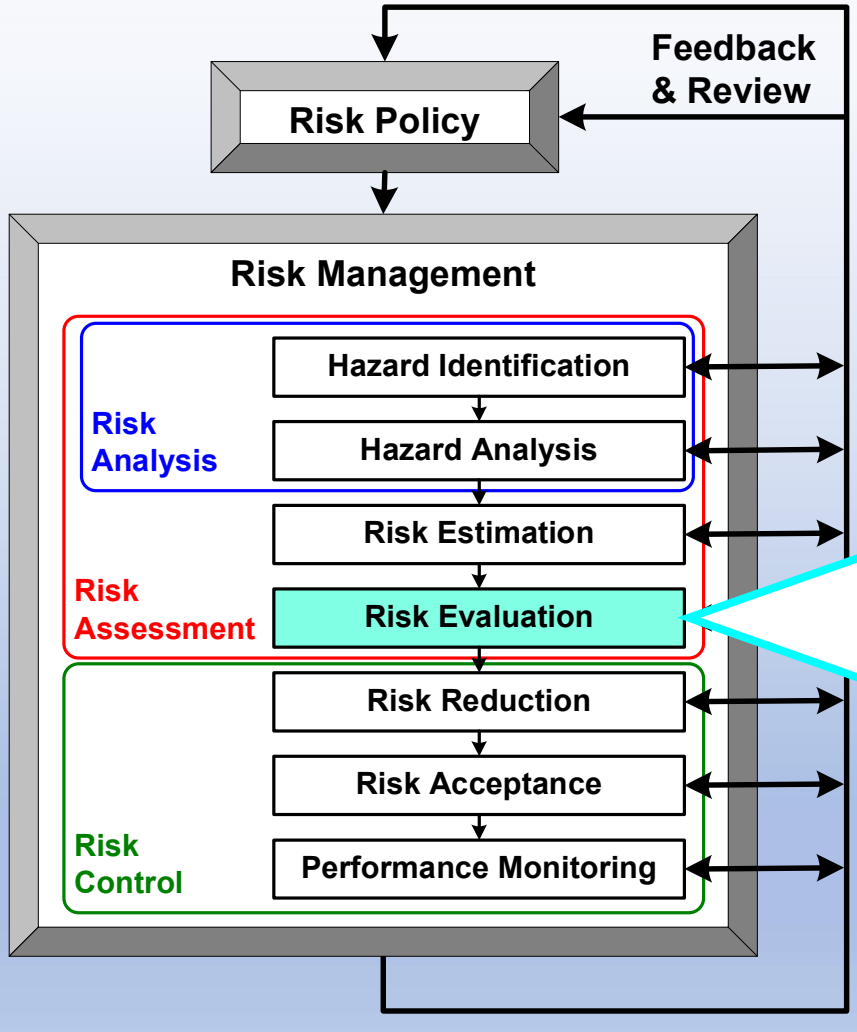
Where is the Risk Matrix used?



Risk Matrix is framework for **Risk Evaluation**:

- Used after Hazards are identified & understood and Risks estimated:
  - How Significant ?
  - Priority for Risk Control
  - Areas for detailed Assessment

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What is a Risk Matrix?

- A Framework for Ranking/Screening “Single Risks” for prioritisation
- Continuum of “Risk Space” divided in ranges
  - Cartesian plot of Impact (Severity) vs Likelihood

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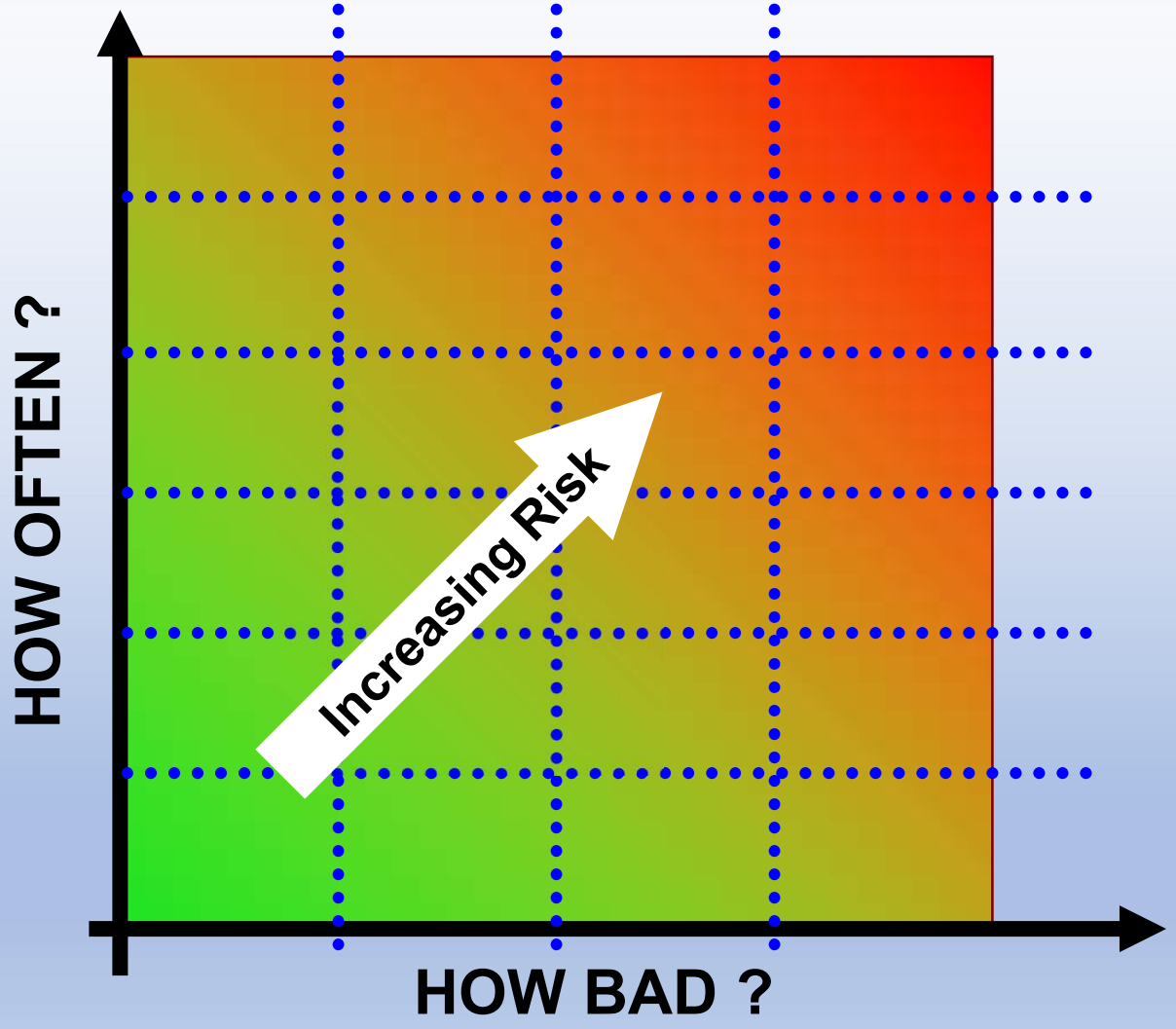
Dividing up the Risk Continuum



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What is a Risk Matrix?

- A Framework for Ranking/Screening “Single Risks” for prioritisation
- Continuum of “Risk Space” divided in ranges
  - Cartesian plot of Impact (Severity) vs Likelihood
- Used to plot Risk Estimates into Risk ranges:
  - Judgement (best guesses) by SMEs
  - Detailed modelling using generic data
  - Historical data

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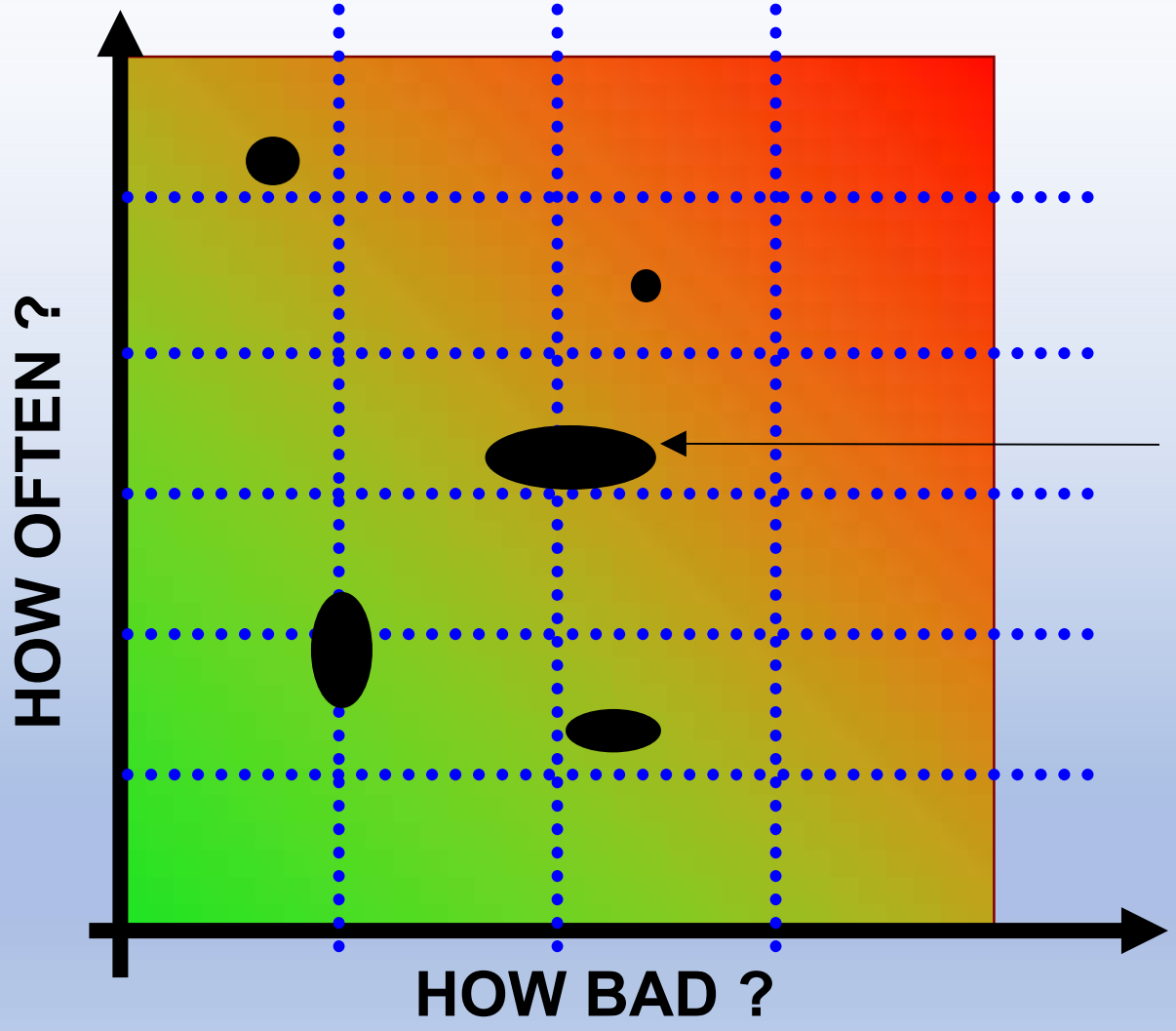
Estimate of Impact & Likelihood



Size and shape represents uncertainty of estimate!

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What is a Risk Matrix?

- A Framework for Ranking/Screening “Single Risks” for prioritisation
- Continuum of “Risk Space” divided in ranges
  - Cartesian plot of Impact (Severity) vs Likelihood
- Used to plot Risk Estimates into Risk Ranges
  - Judgement (guesses) by SMEs
  - Detailed modelling using generic data
  - Historical data
- Used to indicate Relative Significance of each “Single Risk”:
  - Priority (High / Medium / Low)
  - Risk Score / Risk Index
  - Risk Class
  - Expected Loss

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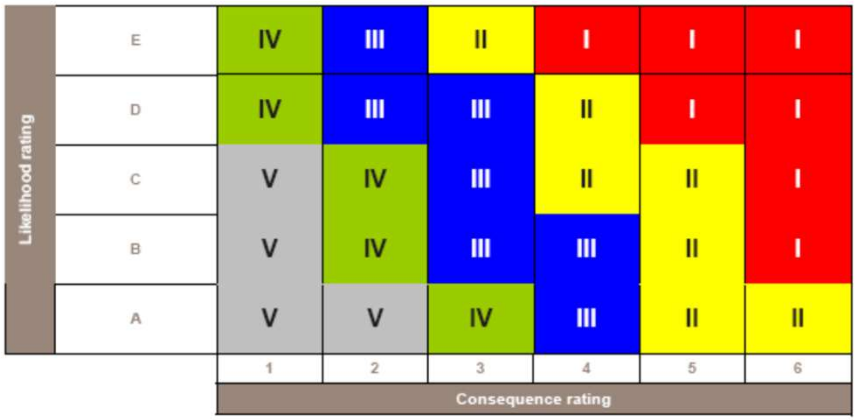
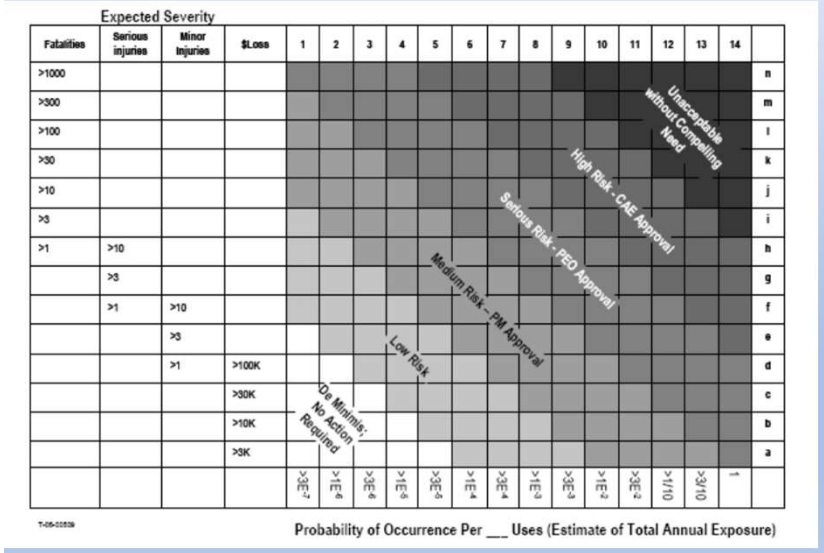
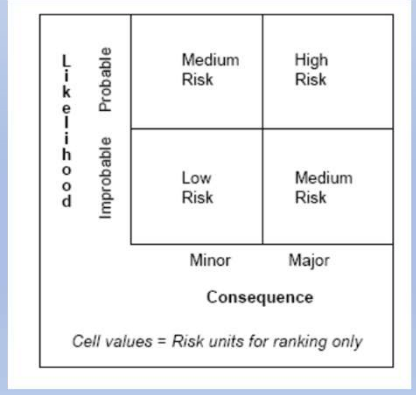
Risk Matrix Examples



CONSEQUENCE					INCREASING PROBABILITY				
Severity Rating	People	Assets	Environ-ment	Reputation	A Rarely occurred in E&P industry	B Happened several times per year in industry	C Has occurred in operating company	D Happened several times per year in operating company	E Happened several times per year in location
0	Zero injury	Zero damage	Zero effect	Zero impact	Manage for continued improvement				
1	Slight injury	Slight damage	Slight effect	Slight impact					
2	Minor injury	Minor damage	Minor effect	Limited impact					
3	Major injury	Local damage	Local effect	Considerable impact					
4	Single fatality	Major damage	Major effect	Major national impact	Incorporate risk reducing measures				
5	Multiple fatalities	Extensive damage	Massive effect	Major international impact				Intolerable	

HAZARD CATEGORY FREQUENCY	CATASTROPHIC	CRITICAL	MARGINAL	NEGLIGIBLE
FREQUENT	1	3	7	13
PROBABLE	2	5	9	16
OCCASIONAL	4	6	11	18
REMOTE	8	10	14	19
IMPROBABLE	12	15	17	20





		Severity Categories					
	Accident Frequency to individual person or group at most risk	Catastrophic More than 100 deaths	Disastrous More than 10 deaths, up to 100 deaths	Critical More than 5 Severe injuries, up to 10 deaths	Major More than 5 Intermediate injuries, up to 5 Severe Injuries	Marginal More than 5 Minor injuries, up to 5 Intermediate injuries	Negligible Up to 5 Minor injuries
Frequent	> 0.1 /year	A	A	A	A	A	C
Probable	$1x10^{-2}$ to 0.1 /year	A	A	A	A	B	C
Occasional	$1x10^{-3}$ to $1x10^{-2}$ /year	A	A	A	B	C	D[41]
Remote	$1x10^{-4}$ to $1x10^{-3}$ /year	A	A	B	C	C	D
Improbable	$1x10^{-5}$ to $1x10^{-4}$ /year	A	B	C	C	D	D
Highly Improbable	$1x10^{-6}$ to $1x10^{-5}$ /year	B	C	C	D	D	D
Incredible	$<10^{-6}$ /year	C	D[42]	D	D	D	D

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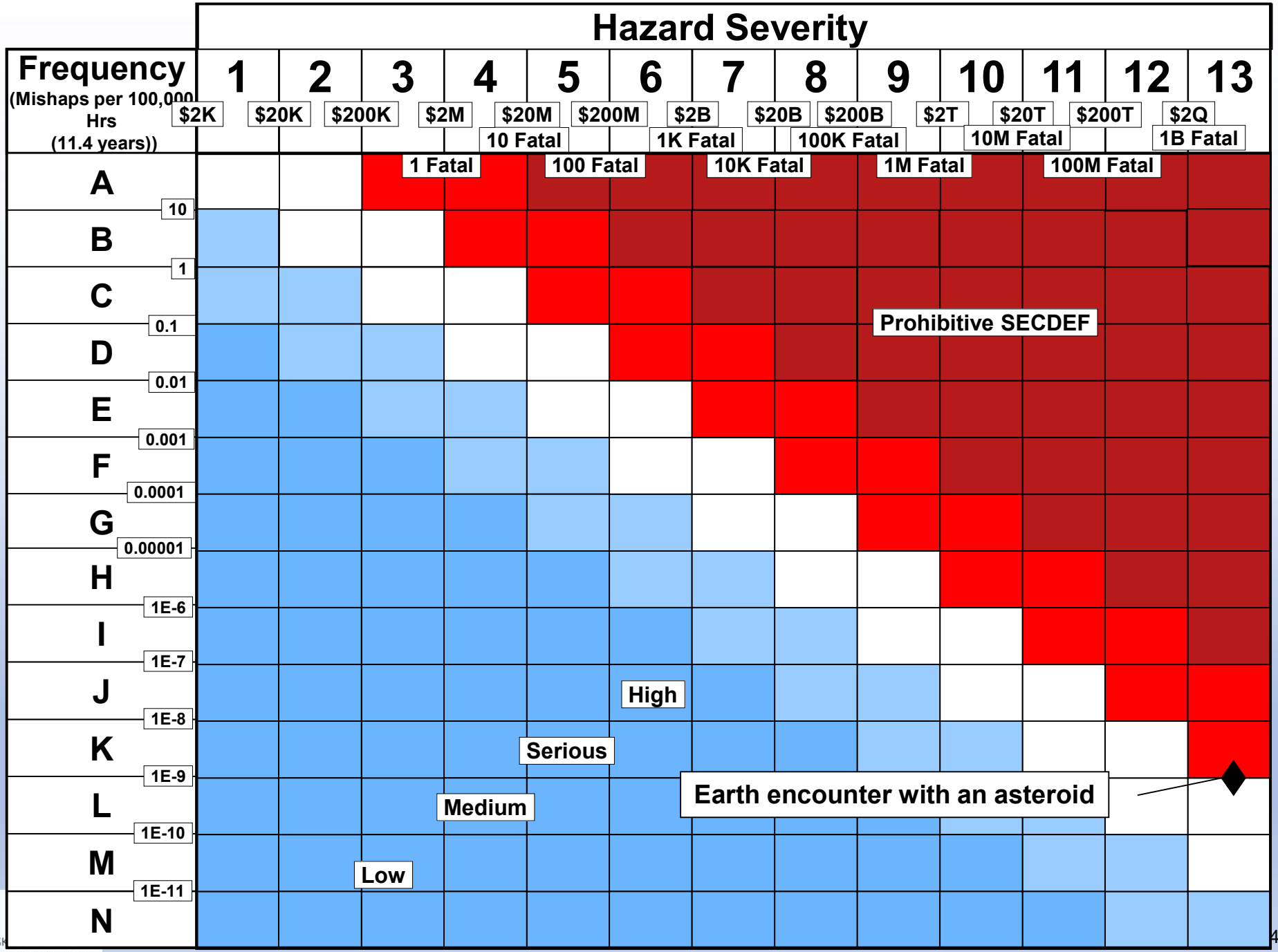
Hazard Severity
Frequency
(Mishaps per 100,000 Hrs (11.4 years))
1
2
3
4
5
6
7
8
9
10
11
12
13
$2K
$20K
$200K
$2M
$20M
$200M
$2B
$20B
$200B
$2T
$20T
$200T
$2Q
10 Fatal
1K Fatal
100K Fatal
10M Fatal
1B Fatal
1 Fatal
100 Fatal
10K Fatal
1M Fatal
100M Fatal
A
B
C
D
E
F
G
H
I
J
K
L
M
N
10
1
0.1
0.01
0.001
0.0001
0.00001
1E-6
1E-7
1E-8
1E-9
1E-10
1E-11
Prohibitive SECDEF
High
Serious
Medium
Low
Earth encounter with an asteroid

What are “Single Risks” ?

- One type of harmful outcome being considered
- Other terms also used:
  - Accident Type, Single Hazard, Partial Risk, Individual Risk, Mishap Risk, Specific Risk
- Not uniquely defined – subjective / matter of style
  - “Loss of Aircraft”
  - “Controlled Flight into Terrain” (CFIT)
  - CFIT due to Human Error
  - Etc.

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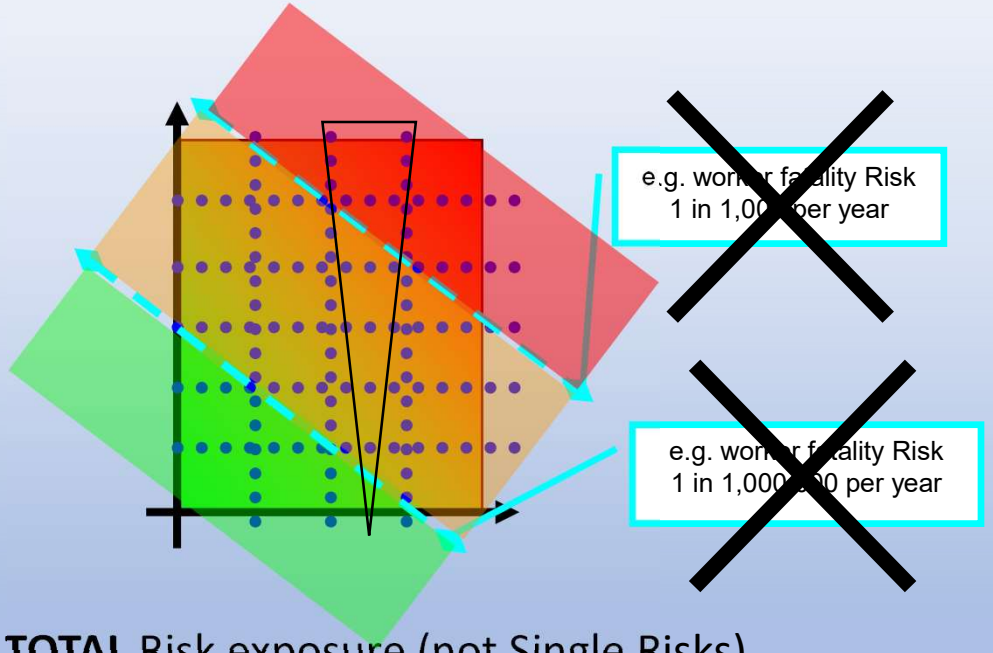
Stretching the Matrix - Impacts

- If Losses in different Categories can be equated:
  - e.g. Explicit or Implicit equivalent Values (£)
- "Severity" scale should be a continuum
  - Not just unrelated Categories that are set adjacent
- How to categorise events with multiple Impacts ?

Matrix to Cover Absolute Risk

- Attractive to make Risk Matrices "Consistent"
  - e.g. across multiple Systems / Projects
- Some Standards suggest using HSE Risk Criteria



- **BUT:**
  - Criteria are for **TOTAL** Risk exposure (not Single Risks)
  - Criteria are person-centric (not System or Activity centric)
  - Risk of one fatality ≠ Individual's Risk of Fatality

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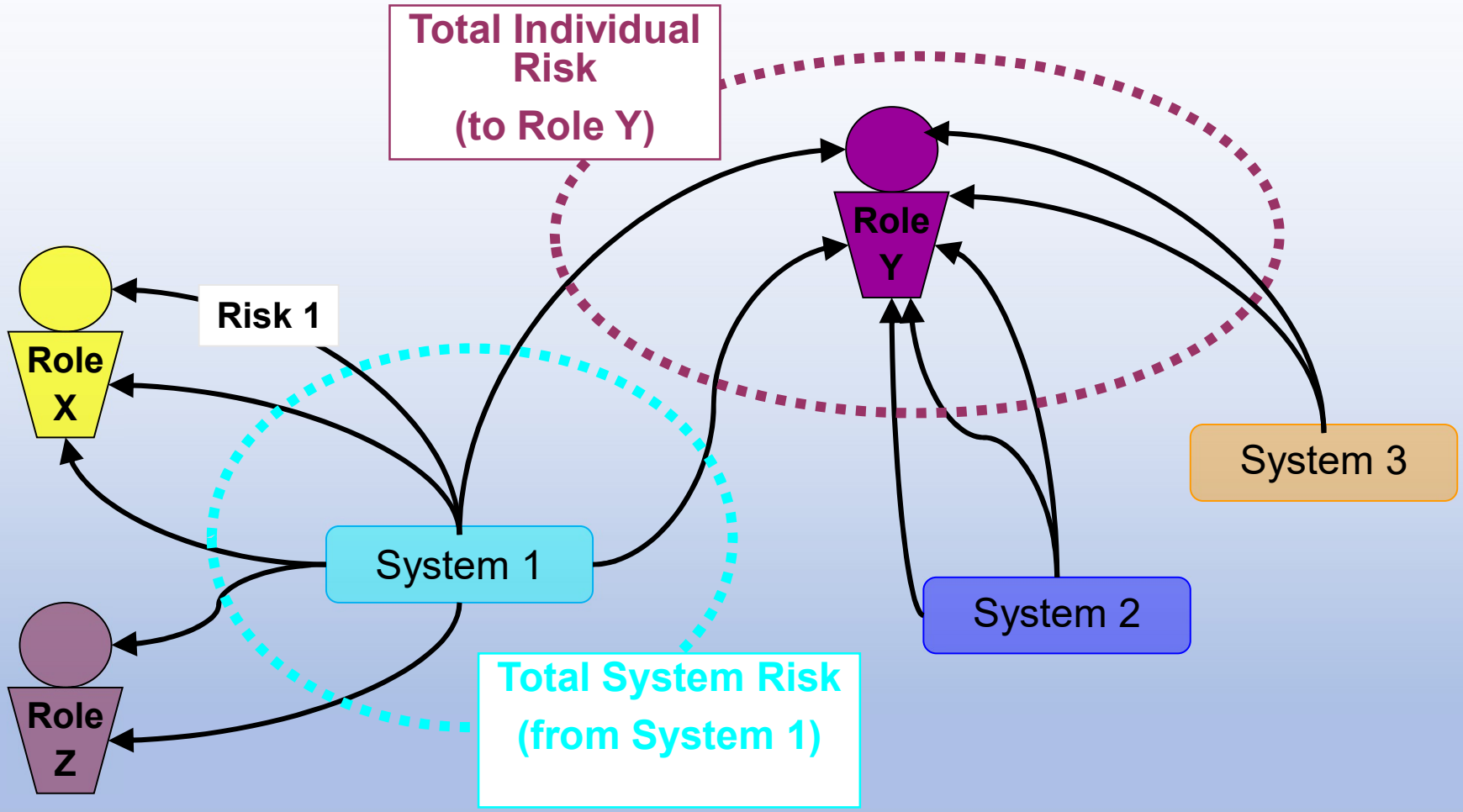
Risk Aggregation Measures (1)



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Risk Aggregation Measures (2)

- Total Individual Risk ("Most at Risk Hypothetical Person")
  - Person-centric
  - Quantitative assessment of all Fatality Risks (not injuries)
  - Should consider all Risk sources (Systems & Activities)

- Total System Risk
  - System-centric measure of expected Loss rate
  - Single measure blurs Low Likelihood / High Impact with High/Low
  - Most measures assume Independence of the Single Risks

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HSE Case Studies: Common Pitfalls - *HSE Research Report 151/2003*

- **Case Study 7:** A large item of gas fired plant was fitted with an enclosure. Occasionally access by personnel was necessary for maintenance purposes. Should a leak of gas occur during the maintenance procedure and ignite, there would be a high likelihood of death or serious injury to the personnel. Data was available on the frequency of leaks from pipework and the probability of ignition.

  This showed the likelihood of this happening coincidentally with the presence of the personnel to be acceptably low compared to published tolerability criteria.

HSE Case Studies: Common Pitfalls - *HSE Research Report 151/2003*

- **Pitfall 'Only considering the risk from one activity':**

  This was a worthless comparison because the personnel may have been at similar risk through other tasks carried out during their working day/week/year and it is the total risk from all activities that should be compared with the criteria.

  In addition, this example illustrates another common pitfall, that of using independent probabilities for events that are not independent.

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  - **Arguing ALARP**
  - Conclusions

What is ALARP ?

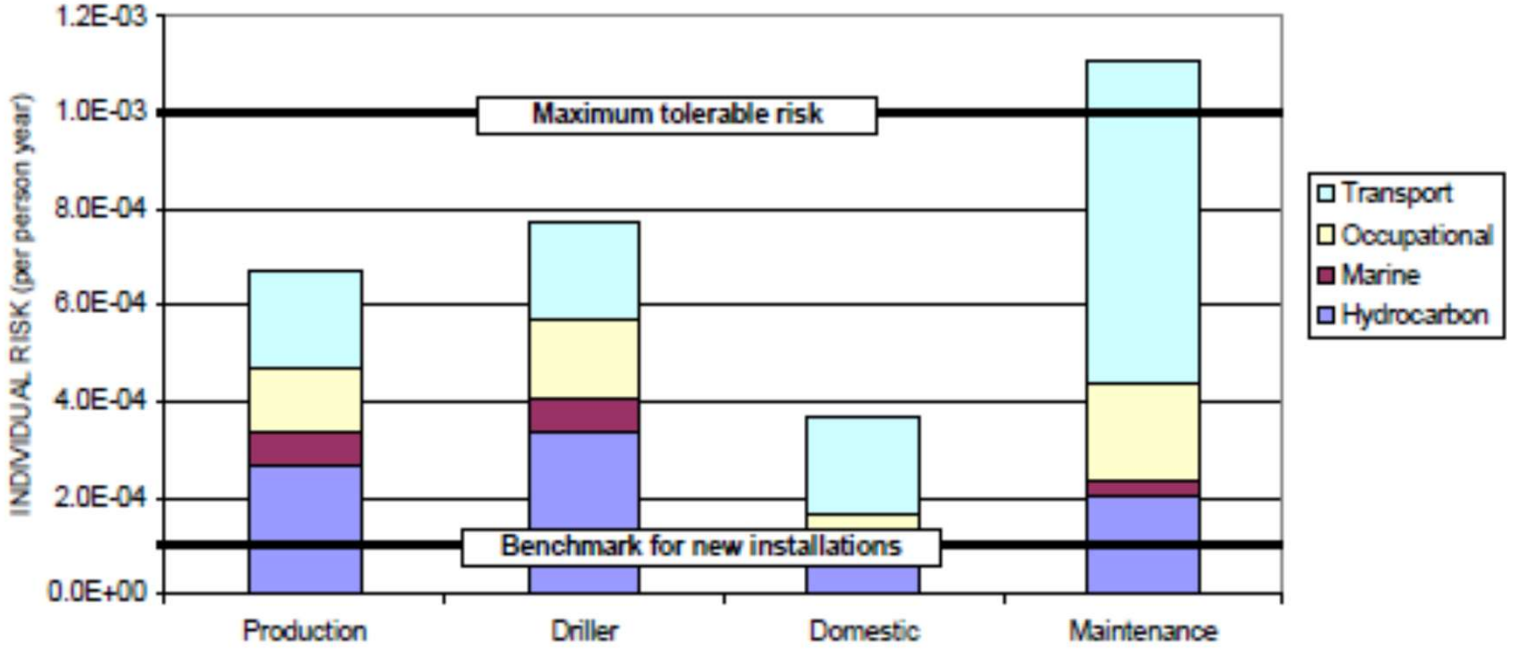
- Safety Risks reduced until they are:
  - **A**s **L**ow **A**s is **R**easonably **P**racticable
- HSE's proposed approach to meet Legal Concept in HSWA:
  - "**S**o **F**ar **A**s **I**s **R**easonably **P**racticable"
- "Duty Holder" judges when Risk exposure should be tolerated
  - Accumulated Risk exposure
  - For hypothetical worst case individual
  - Only tolerate Risk exposure if there is worthwhile benefit
- Balance Residual Risk exposure with spend on Risk Control
  - Weighted in favour of Safety: "Gross Disproportion Factor"
- ALARP status can only be decided by Courts

Hypothetical Worst Case Individual

- Identify hypothetical individuals to represent the different groups exposed to the identified single risks (e.g. Operator, Maintainer, etc).
- Hypothetical individual will be theoretically exposed to the credible worst case scenarios identified.
- Therefore, determine tolerability of aggregated risk for that hypothetical individual
- Reduce aggregated individual risk to ALARP

Aggregated Individual Risk:
HSE Offshore Technology Report 2001/063

Figure 3.1 Example Risk Evaluation



The bar chart shows risks for different individuals on a hypothetical installation. In this case the individual risk for maintenance workers exceeds the HSE tolerability limit. The breakdown shows that this is mainly due to transport and could not be corrected by reducing the marine risk. The risk for the other workers is within the ALARP region, but does not meet the benchmark for new installations.

ALARP Strategies

HSE very clear on priority of ALARP strategies:

1. Good Practice Arguments
   - ACoPs, HSE/ Gov guidance, Standards, standard practice etc.
   - Good practice ≠ Best practice
   - Good practice is a minimum, must be relevant & can change over time

2. First Principles Argument (**Qualitative**)
   - Common Sense, Professional Judgement, Experience

3. First Principles Argument (**Quantitative**)
   - Use of Cost Benefit Analysis (CBA) to support judgement
   - Look for **practicable** methods and then judge "**reasonableness**"
   - **Gross disproportion**, not just simple balance (for human harm only)
   - Rarely required but often contentious

HSE Case Studies: Common Pitfalls - *HSE Research Report 151/2003*

- **Case Study 4:** A system to detect radioactive emissions and automatically shut down the reactor was introduced to all power stations. However, one power station had such a system that proved unreliable, as well as being difficult and costly to maintain. As a result it was decided to veto the system altogether and a review of power stations' safety cases claimed that it was not reasonably practicable to reinstate the system.

  This decision was supported by a quantified ALARP study and CBA which showed that the costs exceeded the benefits by a factor between 27 and 250 and were therefore grossly disproportionate.

HSE Case Studies: Common Pitfalls - *HSE Research Report 151/2003*

- **Pitfall: 'Carrying out a detailed QRA without reference to relevant good practice'**

  HSE challenged this conclusion on the basis that it was too reliant on CBA and did not give sufficient weight to good engineering practice. The safety case was rejected and a programme of work for the reinstatement of the system requested.

  Good practice had not been considered. It is not appropriate to carry out a detailed QRA without first considering whether relevant good practice exists.

  The provision and continuing operation of the system at other similar power stations appeared to be industry good practice and therefore could be considered to be reasonably practicable.

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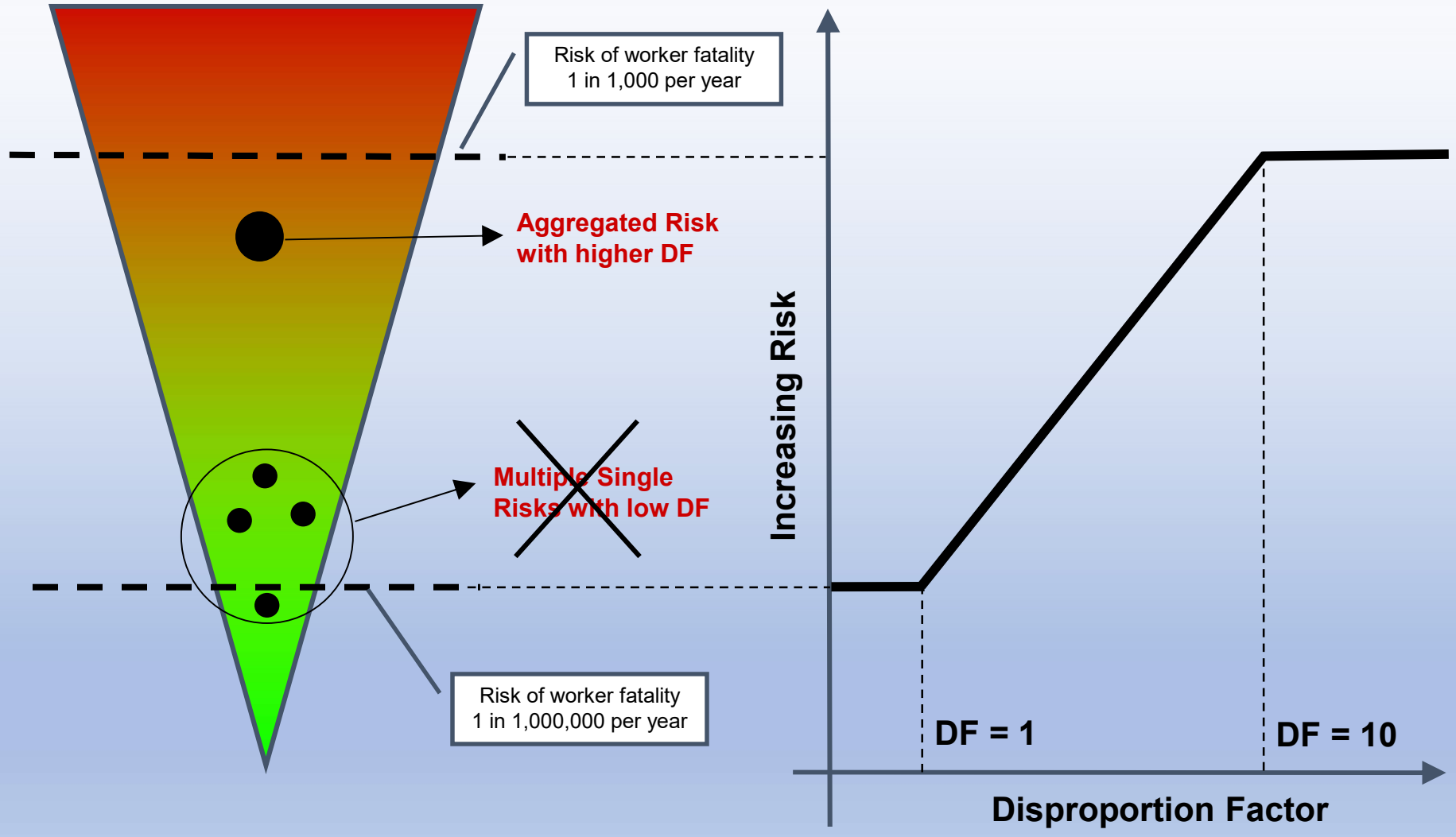
ALARP for “Single Risks” ?

- “Single Risks”
  - One type of harmful outcome being considered
  - Not uniquely defined – matter of style
  - “Good Practice” may be defined at this level
  - ALARP could be argued based on relevant “Good Practice” or “Qualitative First Principles”
- Aggregate Risk
  - Overall Risk of Harm (e.g. to Individual or from System / Activity)
  - Individual doesn’t care how they die, just how likely !
  - Quantitative Criteria & Targets usually defined at this level
  - ALARP argued Quantitatively should consider Aggregate Risk

Gross Disproportion



HSE Case Studies: Common Pitfalls - *HSE Research Report 151/2003*

- **Case Study 20:** A company's COMAH safety report tried to demonstrate that the site's risk was ALARP by comparing the risk from the identified hazardous scenarios to the tolerability criteria for individual and societal risk found in HSE (R2P2). The risk from each scenario was found to be below the tolerable level and therefore judged to be broadly acceptable.

HSE Case Studies: Common Pitfalls - *HSE Research Report 151/2003*

- **Pitfall: 'Inappropriate use of risk criteria':**

  The criteria in HSE (R2P2) are intended to be used for overall individual risk or societal risk. They are therefore not suitable when trying to determine whether or not the risk from individual hazardous scenarios is ALARP. The risk from all hazardous scenarios should be aggregated before comparing to the criteria.

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Stretching the Matrix Technique

- Covering different groups of people in one Matrix
- Covering non-Safety Impacts:
  - Environmental Harm
  - Asset Damage
  - Financial Loss
  - Reputation Damage
- **Absolute** Risk (not just relative)
  - e.g. Link to HSE Criteria for Individual &/or Societal Risk (i.e. R2P2)
- Arguing Tolerability of Risk
- Arguing ALARP

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Conclusions – Risk Matrices

- **Good for:**
  - Prioritising "Single Risks" for Risk Reduction
  - Identifying where to spend time and effort reducing risks for greatest benefit
  - Quick appreciation of Risk drivers
  - Communication with non-Specialists
  - Identifying aspects for more detailed Assessment

- **Bad for / not for:**
  - Judging whether **Quantitative** Risk targets have been met
  - Understanding Aggregate / Total Risk Exposure
  - Examining Societal Risk
  - Understanding **Absolute** Risk
  - Comparing Risks across dissimilar cases
  - Arguing Tolerability & ALARP

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Conclusions

- Risk Matrix is a powerful broad brush Tool for Risk Evaluation
- Risk Matrices are not the universal answer, as:
  - Consider “Single Risks” only
  - Semi-quantitative technique
  - Rank “Single Risks” by significance for control & more detailed assessment
  - Matrix boundaries set using HSE Individual Risk Criteria usually flawed
- Some sectors have stretched the Risk Matrix too far !

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  - Rank “Single Risks” by significance for control & more detailed assessment
  - Matrix boundaries set using HSE Individual Risk Criteria usually flawed
- ALARP argued from Good Practice given priority
- Where ALARP argued Quantitatively (First Principles):
  - Risk and GDF will appear too low if only “Single Risks” considered
- Some sectors have stretched the Risk Matrix too far !

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Any Questions?

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