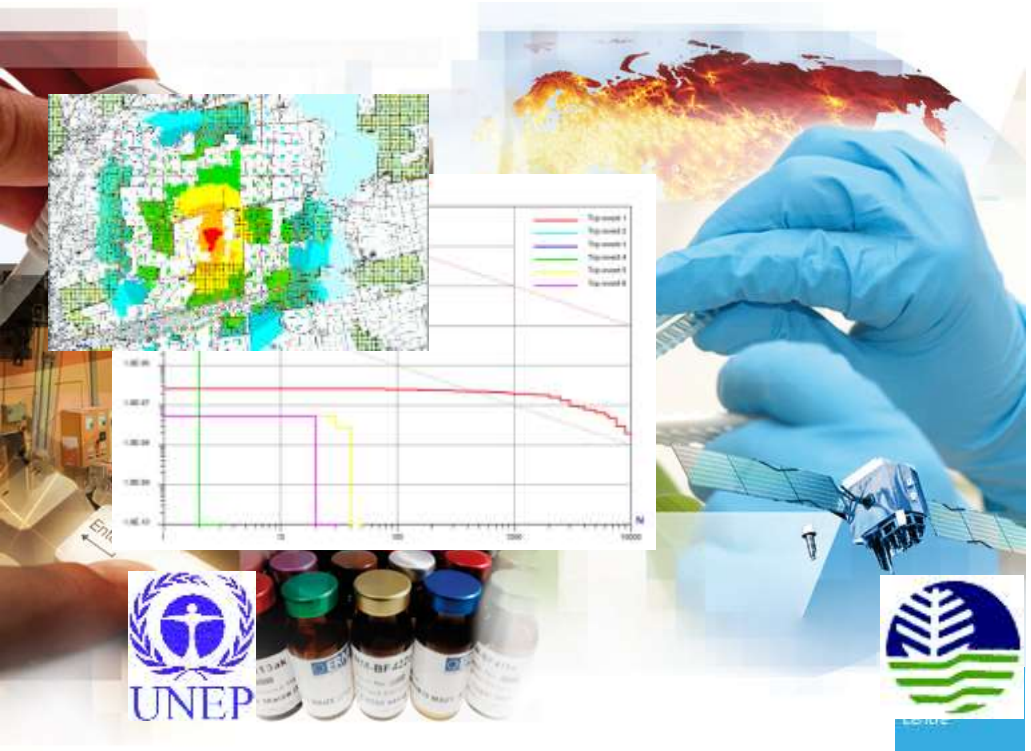
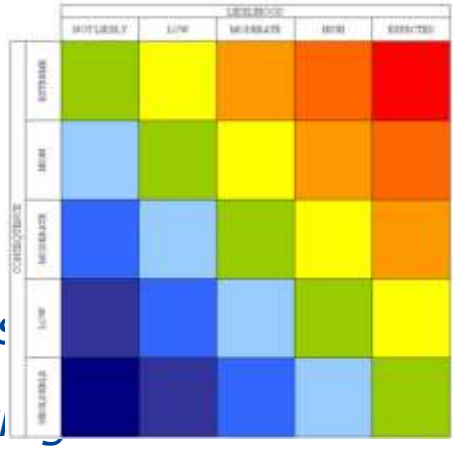
Overview of the risk assessment process



www.jrc.ec.europa.eu



Serving s

Stimulati

Supporting legislation

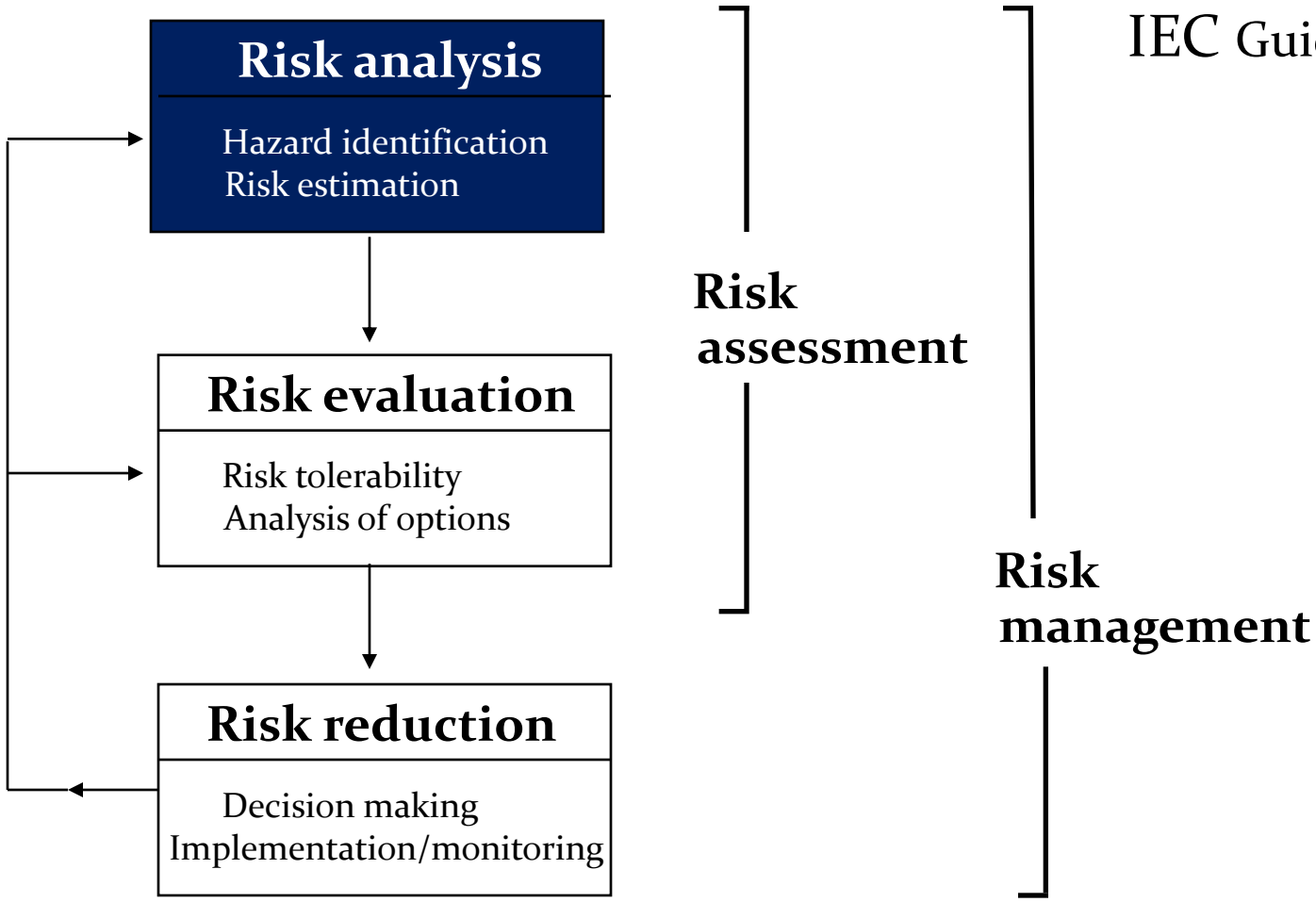
Content

- Overview of Risk Analysis
- The Quantitative Risk Analysis Process
- Different Approaches
- Frequency and Consequence Assessment
- Sources of Uncertainties
- General Conclusions

RISK ANALYSIS, RISK ASSESSMENT, RISK MANAGEMENT

IEC 300-3-9 (1995)

IEC Guide 73 (2002)



Objectives

- To provide a general overview of quantitative risk analysis for industrial establishments
- To be able to understand the key elements of the quantitative risk analysis process
- To understand and make familiar the main approaches and techniques for quantitative risk analysis

What is Risk?

Risk = set of <scenario, frequency, consequence>

What may go wrong?

How frequently could it occur?

How dangerous is it?

Risk = hazard / safeguards

What is Quantitative Risk Analysis?

complex, but well structured process, **to provide a measure of the risks** associated with the *process*, *storage* and *transport* of hazardous substances

Identify Hazards

Estimate the Risks associated to possible accidents scenarios leading to damage

Final objective

Determine components, safety measures, and/or human actions necessary for plant safety

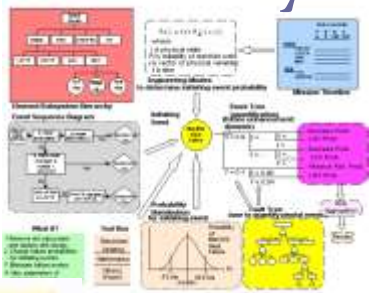
Who are the main players?

European Commission

Plant Operator

Competent Authority

Risk Analysis



Chemical establishment

Public

Joint Research Centre

European Commission

Risk assessment is a complex process

- It requires specific expertise in risk analysis itself
- It requires specialised knowledge about the object being analysed (e.g., chemical process safety)

EVALUATE A RISK ANALYSIS

- Evaluators should understand the fundamentals of risk assessment
- It is recommended there is access to an expert with specialized knowledge of industrial risk assessment

Competent Authority

In the Safety Report …

- to **demonstrate** that a particular **scenario no longer presents** a major-accident hazard due to the measures in place
- to **demonstrate** that the **extent** of the effects of a particular scenario have been **limited**
- to **demonstrate** the efficiency and the effectiveness of **mitigation measures** put in place
- to establish whether the activity is **acceptable** or not
- to establish whether **further mitigating measures** are necessary
- to provide information for competent authority obligations (e.g., emergency plans, land-use planning)

OUTCOME OF A RISK ANALYSIS

AN ESTIMATE OF THE RISK

RISK =
FREQUENCY X SEVERITY

How many and how often?

RISK ESTIMATE: A FAMILIAR EXAMPLE

TEN COUNTRIES WITH THE HIGHEST ANNUAL MOTOR VEHICLE DEATH RATES, MID-1990s

COUNTRY	DEATHS PER 100,000
(1) Portugal	24.9
(2) Greece	23.3
(3) Venezuela	22.3
(4) Russian Federation	22.3
(5) Slovenia	14.3
(6) Cuba	18.3
(7) Poland	18.3
(8) Mauritius	17.8
(9) Colombia	17.4
(10) Hungary	17.0

From 2002 INTERNATIONAL ACCIDENT FACTS (Second Edition). Published by the National Safety Council (NSC) using WHO statistics

www.nsc.org

HAZARDOUS INSTALLATION HYPOTHETICAL EXAMPLE

For example, for the atmospheric tank, you might have the following (hypothetical, not a real situation)

10^{-3} (1/1000) = Small fire, 1 tank destroyed
Risk of 1 **tank** destroyed = 0.01% = 1/1000 = 10^{-3}
Acceptable or unacceptable?

10^{-5} (1/100,000) = Explosion, 2 workers injured =
Risk of **2 workers** injured = .002% = 2/100,000 = $2 * 10^{-5}$
Acceptable or unacceptable?

10^{-6} (1/1,000,000) = Major fire, > 5 people killed =
Risk of **5 people** killed = .0005% = $5 * 10^{-6}$
Acceptable or unacceptable?

STARTING POINT

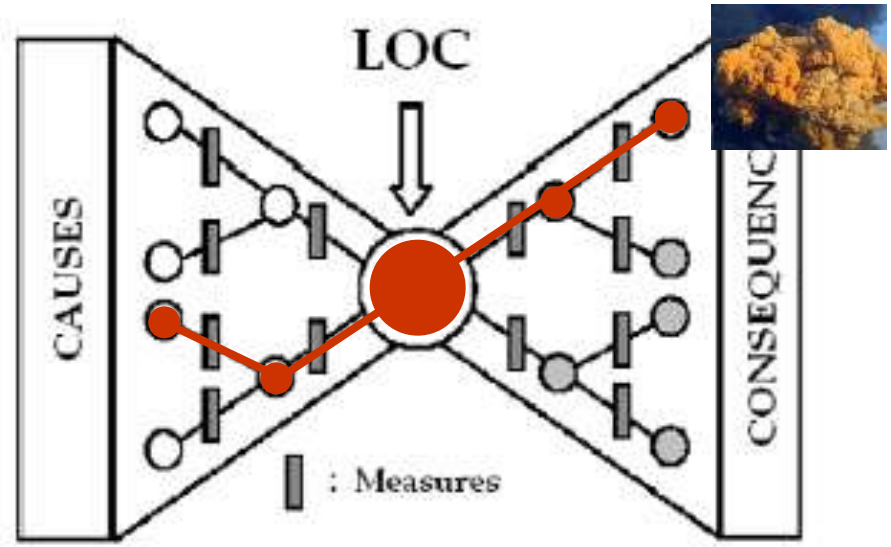
Initiating event (undesired)= loss of containment (**LOC**)

- e.g., vessel rupture or leak, pipe rupture, the developing event:
- fire, explosion, release of toxics

Accident Scenario

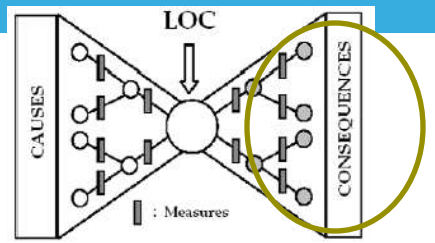
GENERAL "BOW-TIE" APPROACH

- The centre of the diagram is the **loss of containment** event (LOC)
- The bow-tie left side depicts the overall possible **causes**.
- The left-side vertical bars refer to the measures (barriers) in place to **prevent** the release of dangerous substances and control escalation.
- The bow-tie right side describes possible **accidental scenarios**
- The right-side vertical bars in the bow-tie right side refer to the measures to **mitigate** consequences.



bow-tie diagram

TYPICAL CONSEQUENCES



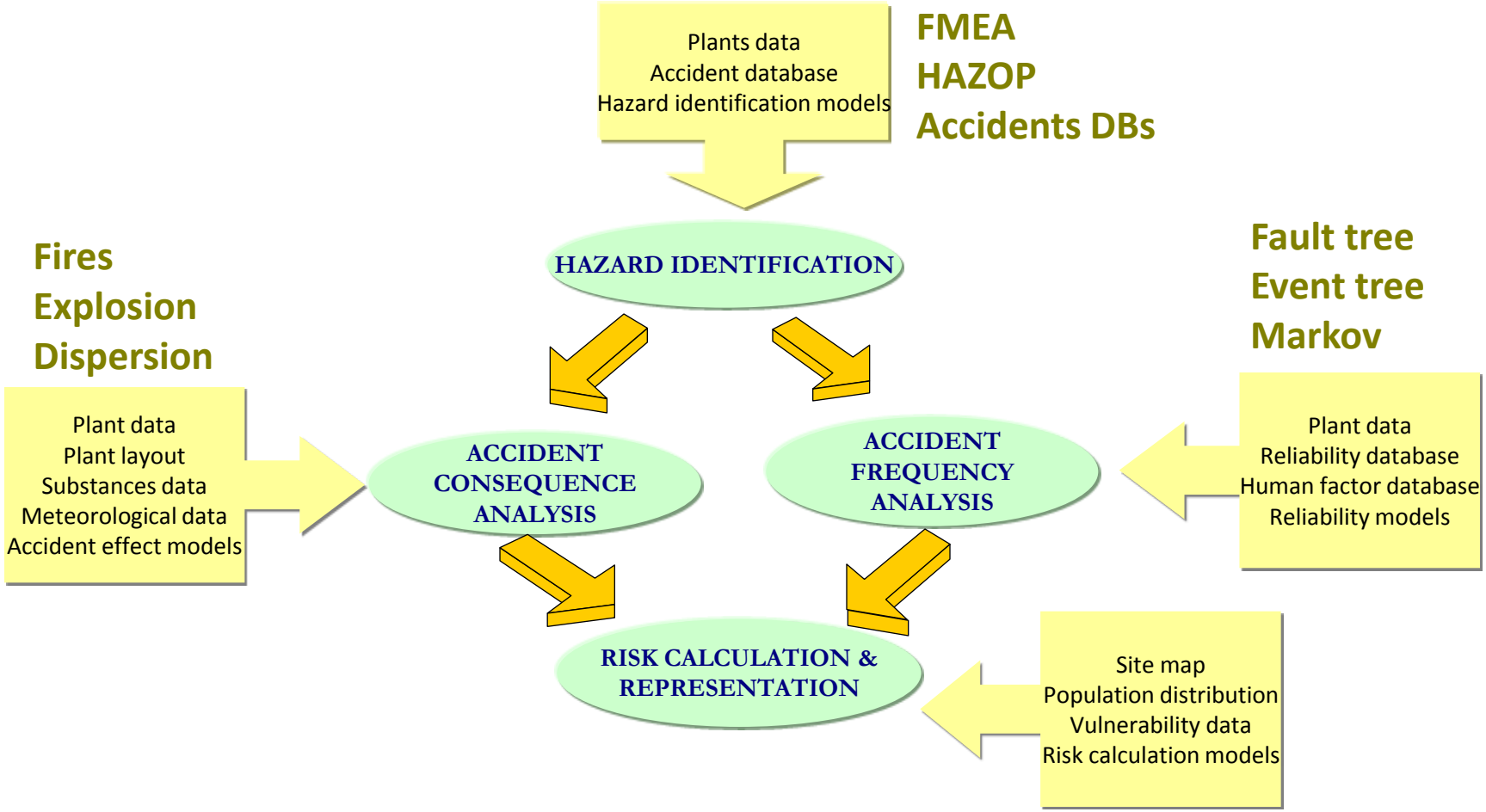
Fire

Explosion

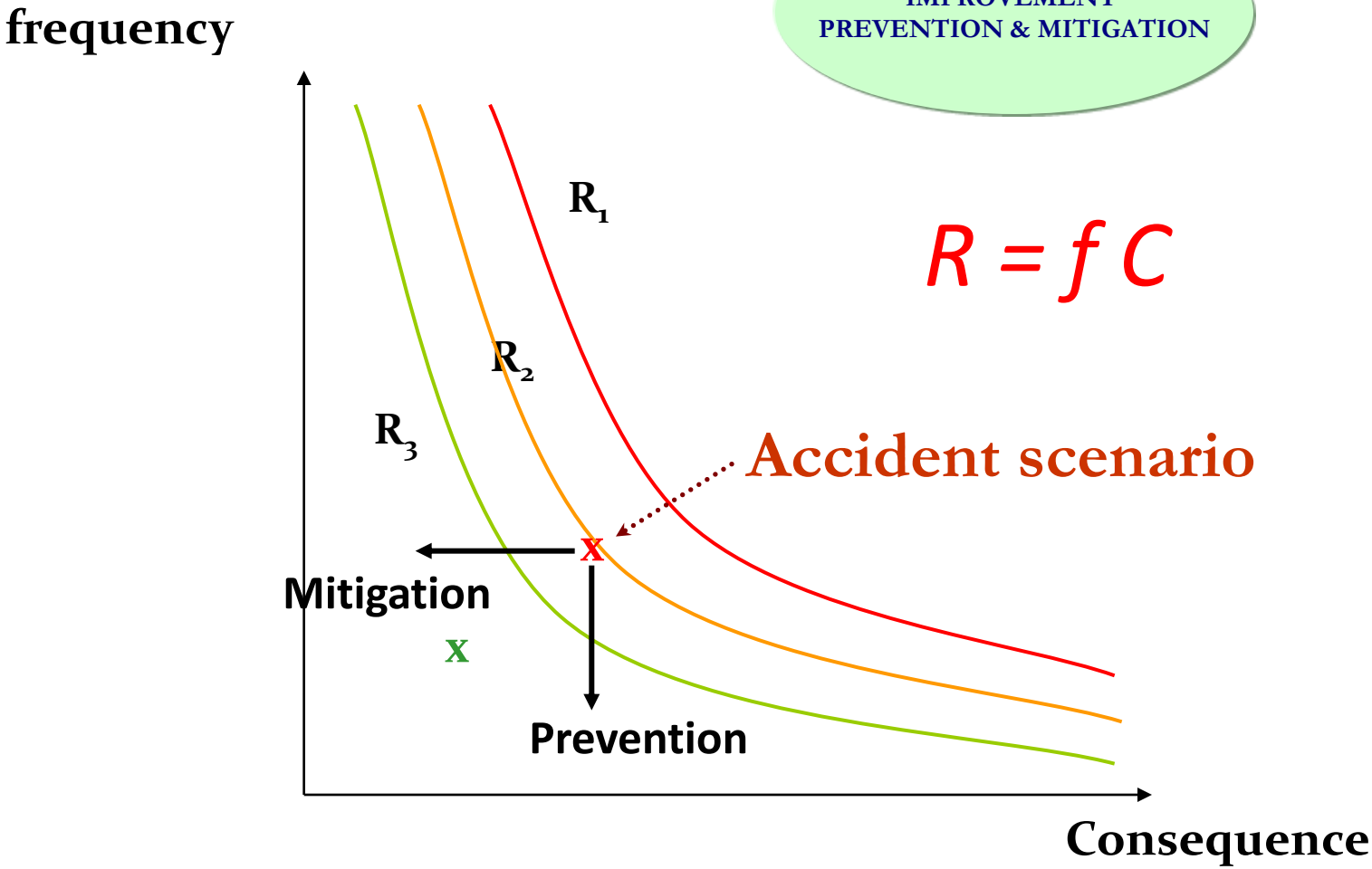
Toxic release

Damage

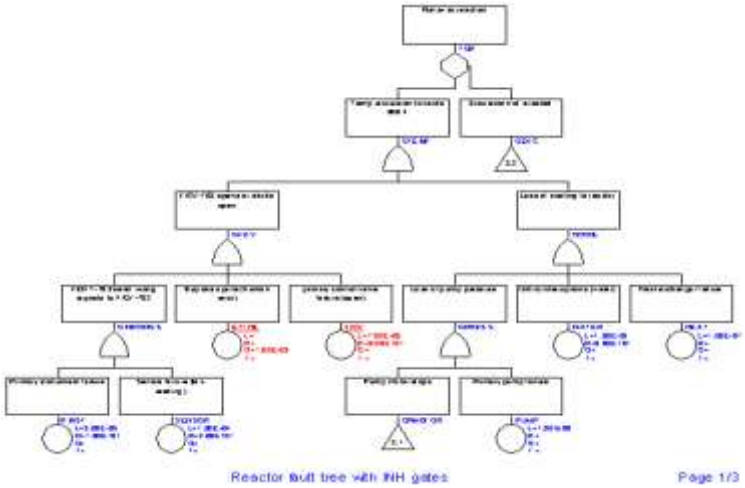
Input Data and Models

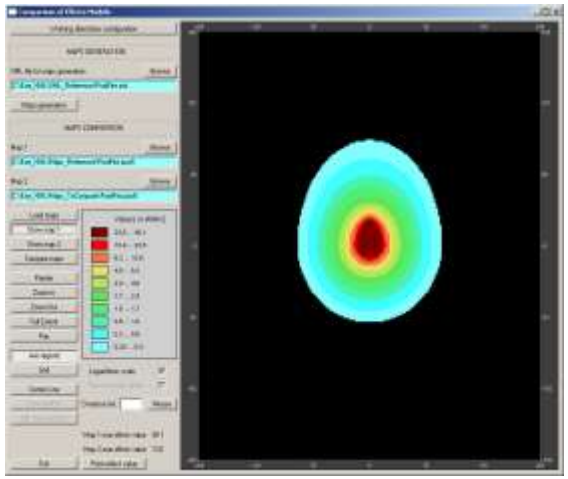


IMPROVEMENT
PREVENTION & MITIGATION



Frequency and Consequence Assessment





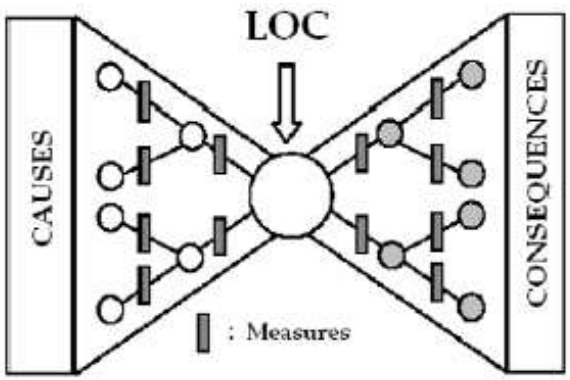
Frequency Assessment

Expert judgement

Use of databases

Other Methods

- Fault-Tree Analysis
- Event-Tree Analysis
- Markov



How frequent is it?

Different Scenarios associated with the same LOC

Basic events

CONSEQUENCE ASSESSMENT

European Commission

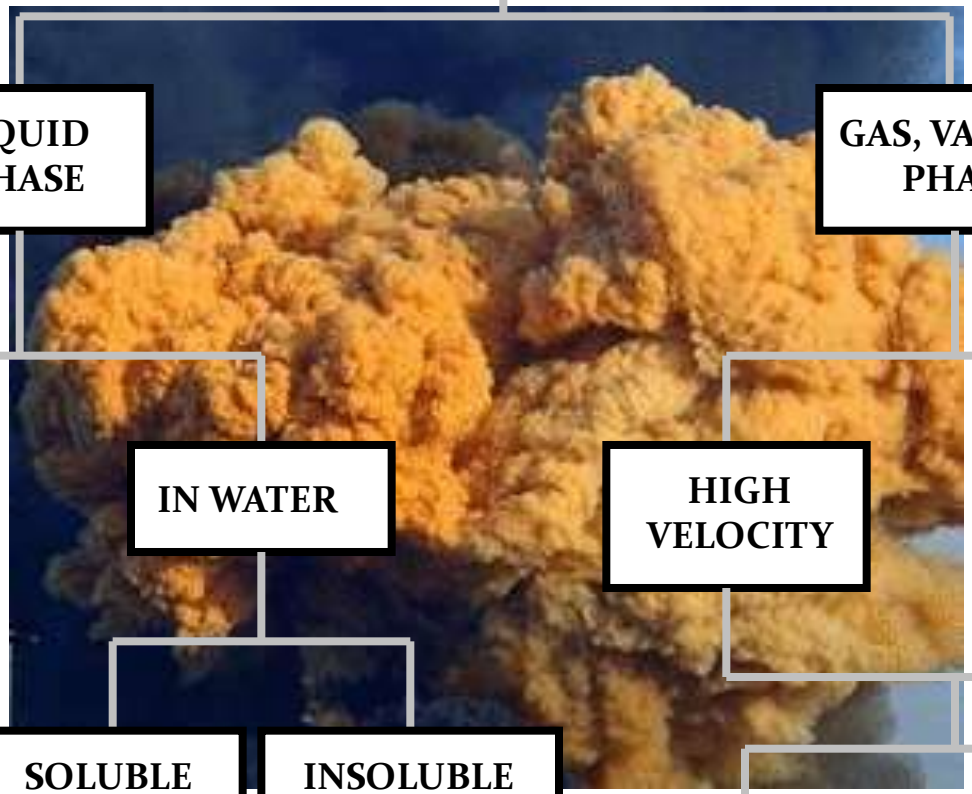
How dangerous is it?

Used to estimate:

- the extent to which damage may occur as a consequence of an accident

Joint Research Centre

Toxic release

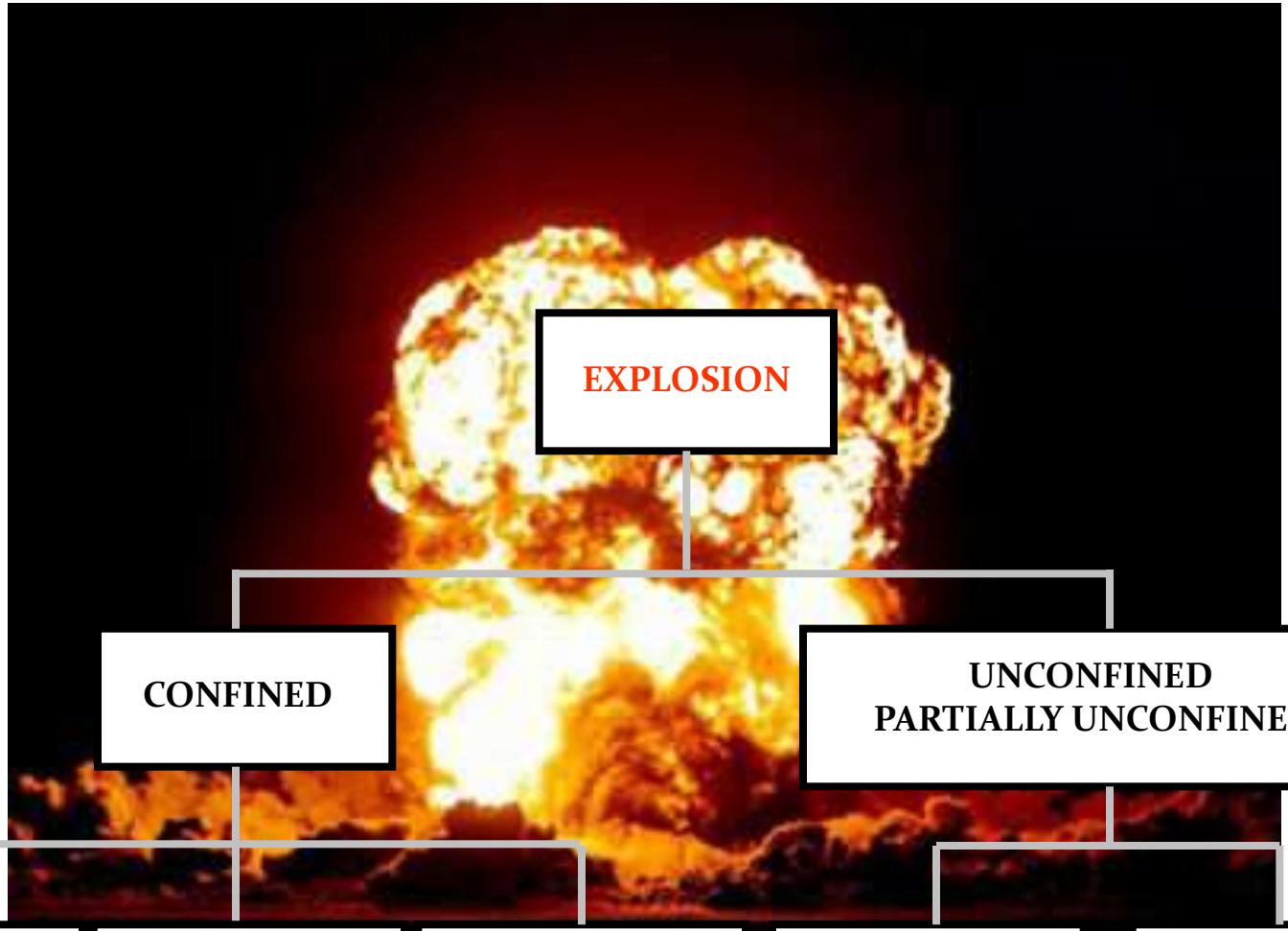


TOXIC RELEASE

- **LIQUID PHASE**
  - **ON GROUND**
    - Pool formation and evaporation
  - **IN WATER**
    - **SOLUBLE FLUID**
      - Liquid/liquid dispersion
    - **INSOLUBLE FLUID**
      - Pool formation
- **GAS, VAPOUR PHASE**
  - **HIGH VELOCITY**
    - **LESS DENSE THAN AIR**
      - Dispersion for Turbulence (Buoyant)
    - **MORE DENSE THAN AIR**
      - Dispersion for gravity
  - **LOW VELOCITY**

Joint Research Centre

Explosion



EXPLOSION

- **CONFINED**
  - **POWDERS**
  - **UNSTABLE REACTIONS**
  - **FLAMABLE GAS AND VAPOURS**
- **UNCONFINED PARTIALLY UNCONFINED**
  - **FLAMABLE GAS AND VAPOURS**
  - **CRYOGENIC LIQUIDS**

Fire

FIRE

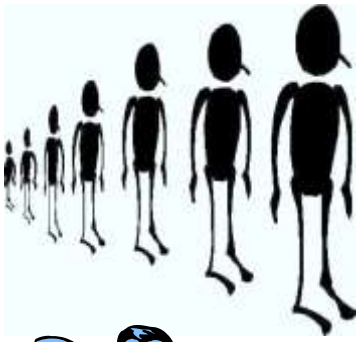
- **POOL FIRE**

- **FLASH FIRE**

- **FIREBALL**

- **JET FIRE**

From Damage to Consequences



PHYSICAL DAMAGE

VULNERABILITY

POPULATION

INFRASTRUCTURE

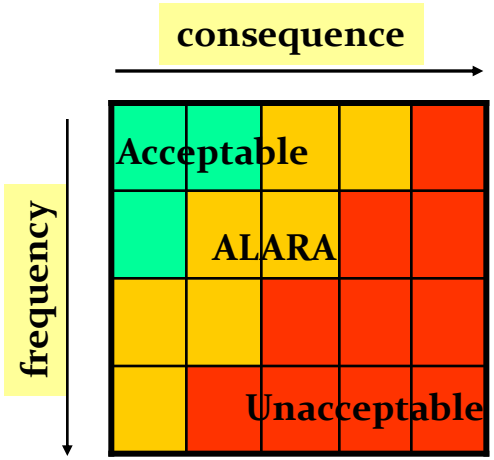
DAMAGE CRITERIA

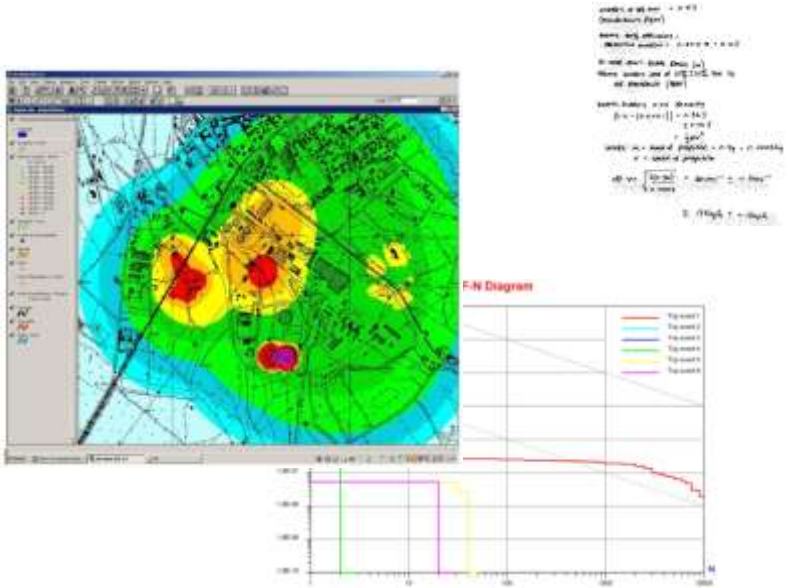
PROBIT MODELS

Consequence Assessment in practice

- It is an **expert activity** (often conducted by external consultants) and **expensive**
- It is not only conducted for risk assessment purposes (e.g. **emergency planning**, LUP)
- Sophisticated software tools are very **expensive** although some **freeware is available** (ALHOA, etc)
- Input and output data are not reported in a standardised way, which makes **interoperability** amongst different packages very difficult

Risk Calculation & representation





Risk matrix

	Consequence Severity Category				
Freq.	5	4	3	2	1
A				Not Acceptable	
B			ALARP		
C					
D	Acceptable				
E					

Severity Category	Qualitative Definition	Quantitative Definition
		injury
1	catastrophic	multiple fatalities
2	major	single fatality, multiple injuries
3	very serious	permanent disabling injury
4	serious	serious injury, full recovery
5	minor	lost-time injury, short absence from work

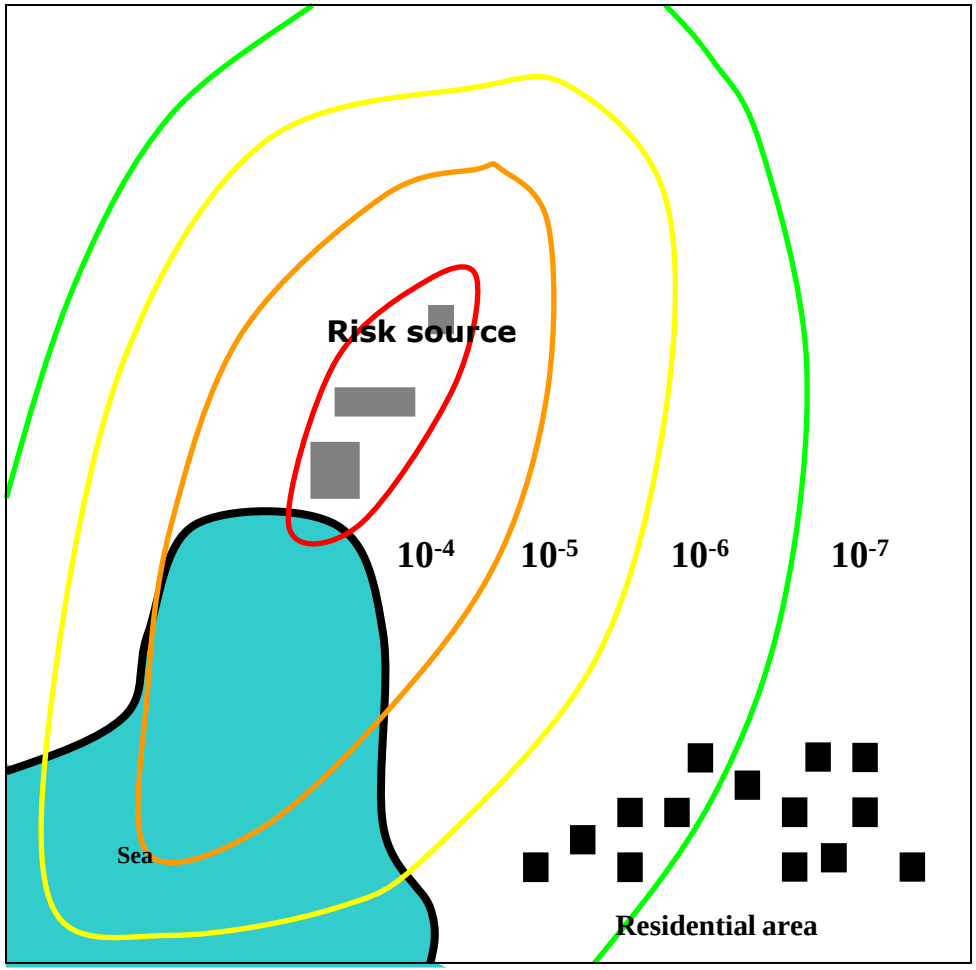
Severity Category	Qualitative Definition	Quantitative Definition (p.a.)
Cont.	Continuous	Weighting factor
A	likely once in next year	1
B	possible but not likely	0.1
C	unlikely	0.01
D	very unlikely	0.001
E	remote	0.0001

Risk indicators

Individual Risk

annual frequency of occurrence of the reference damage (e.g., the death), in any point of the geographical area, for a person present

This is a useful figure to characterise the risk in a given location.

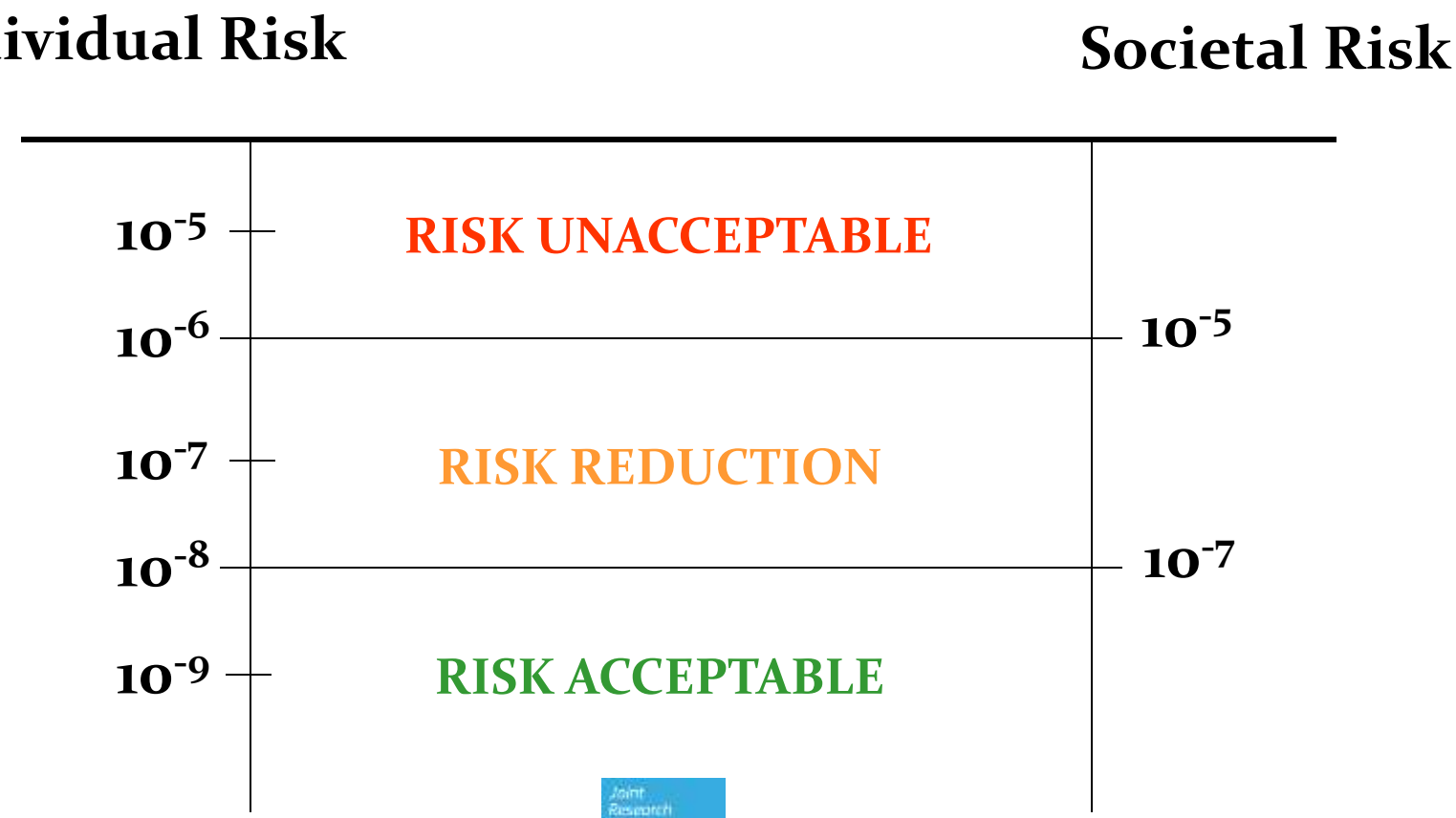


Risk Acceptance Criteria

What is acceptable depend upon current societal tolerance

- What is tolerable today may not be considered as tolerable tomorrow
- What is tolerable somewhere may not be tolerable somewhere else

Risk Criteria



Uncertainty: example

BEQUAR Benchmark

Fabbri et al., J Hazard Mater. 2009 Mar 15;162(2-3):1465-76

KEY CONCEPTS TO REMEMBER

- Analysis completeness can never be assured
- Uncertainty on the estimated risk figure cannot be avoided, however sensitivity studies can help filling the gap
- Transparency in the process is essential (hypothesis, data and modelling)

Risk Analysis is not necessarily important to get the exact (absolute) figure of risk. The overall process of risk analysis helps improving awareness of the critical aspects of the plant

Training Workshop on Chemical Accident Prevention Program

Thank you