Process Safety and Loss Management

Session 6

Hazard and Risk Assessment,
Frequency and Consequence Analysis Techniques

51st Chemical Engineering Conference
October, 2001
Halifax, Nova Scotia

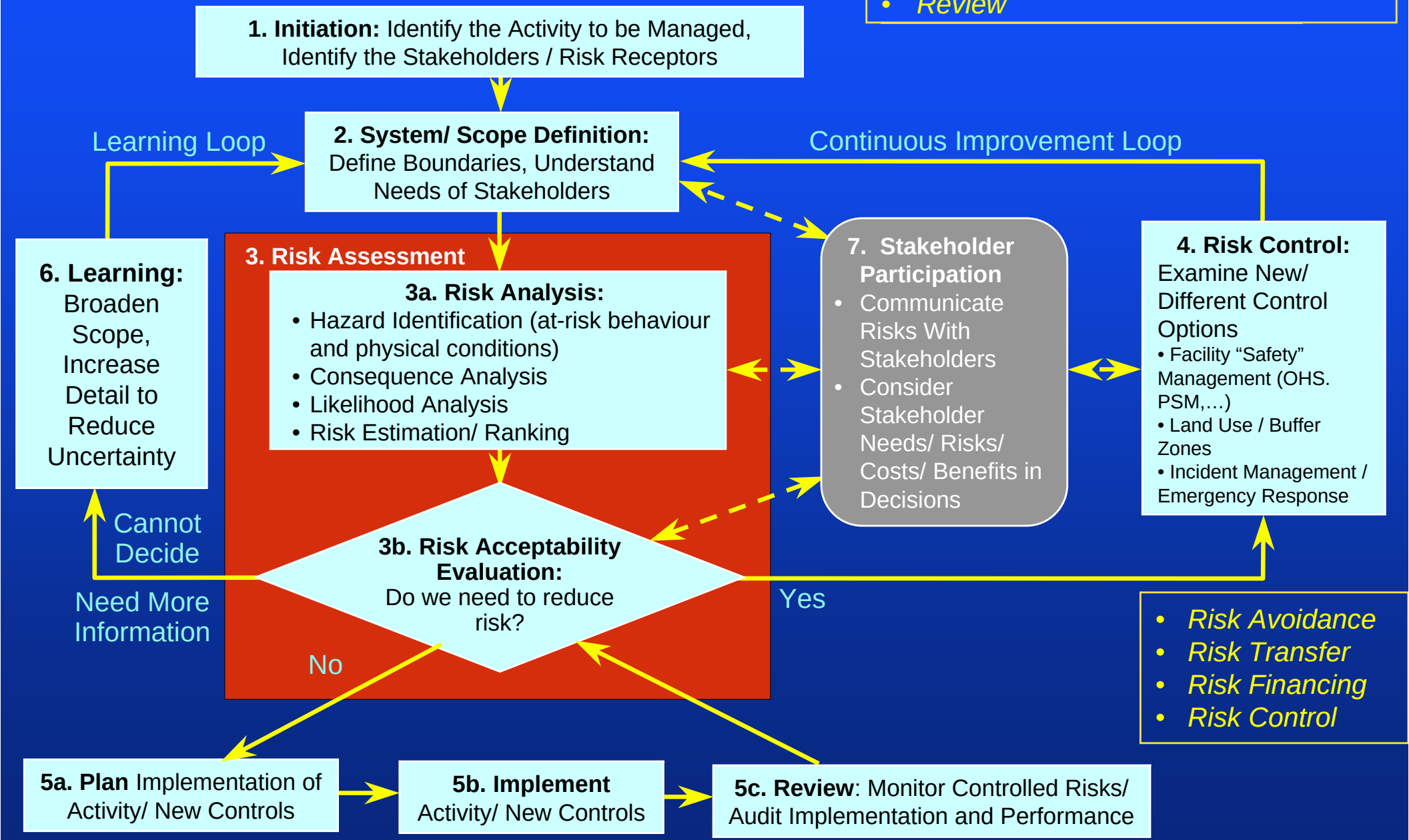
Chair: Ertugrul Alp, Ph.D., P.Eng.
ALP & ASSOCIATES Incorporated
87 Topham Crescent, Richmond Hill, Ontario, L4C 9E9, Canada
Tel: 905-508-2595, Fax: 905-508-2679
E-mail:ErtugrulAlp@home.com, Web Site: www.Alp-Risk.ca

Topics covered

- Alp – Risk management system and risk assessment techniques
- Yugo Ivanovich – Risk management system focusing on SHE
- Leo Jansen – NEB's index method of risk assessment
- Christian Etowa – Dow's index method of risk assessment – inherent safety
- Mike Morgan – Consequence analysis/ learning loop
- Gerry Phillips – CARAT – Improving Stakeholder Participation
- Mark Riley – Risk control/ engineering – Monitoring
- Faisal Khan – SWeHI – Index method of risk assessment, combining Fire/ Explosion and Toxic/ Corrosive hazards
  - Suggest: keep the units of measurement in B (consequence) and A (1/frequency), rather than burying them into an index
- Brian Kelly – scare with hazardous events, overview of PSM – risk management focusing on hazardous materials and systems

Risk Management Process

Classical Management Process Steps
- *Vision: Set Policy and Direction*
- *Assess*
- *Plan*
- *Implement*
- *Review*



- *Risk Avoidance*
- *Risk Transfer*
- *Risk Financing*
- *Risk Control*

Thank you all

- Participants
- Speakers
- Moderators
- Our volunteer

Risk Assessment Techniques for Process Safety and Risk Management

A Short Overview

Presented by Ertugrul Alp, Ph.D., P.Eng.

51st Chemical Engineering Conference
October, 2001
Halifax, Nova Scotia

ALP & ASSOCIATES Incorporated
87 Topham Crescent, Richmond Hill, Ontario, L4C 9E9, Canada
Tel: 905-508-2595, Fax: 905-508-2679
E-mail:ErtugrulAlp@home.com, Web Site: www.Alp-Risk.ca

Objectives

- Provide an overview of
  - risk concepts
  - the risk management process
  - risk assessment techniques
  - measures for representing different types of risk

  so that you will gain an understanding of the usefulness and limitations of different risk assessment techniques as applied to process safety management.

- Our focus will be industries where different types of hazards are inherent in their business processes, in particular those that deal with hazardous materials.

Risk Concepts

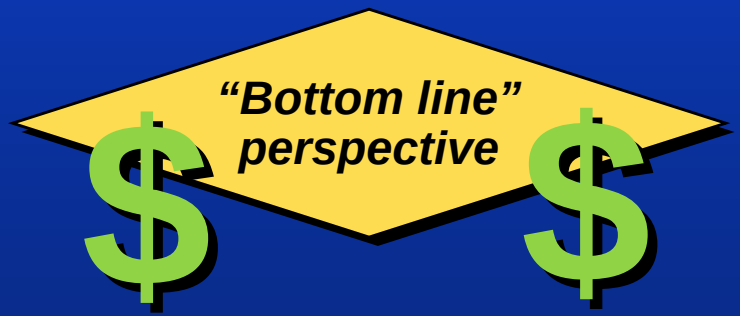
- We are faced with many different types of risks in day-to-day operations:

Risk "Receptor" Perspective

- employee risk
- public risk
- environmental risk
- production risk
- property risk
- shareholder risk

Risk "Source" Perspective

- facility risk
- transportation risk
- project risk
- market risk
- currency risk
- public outrage risk



- financial risk
- integrated risk
- enterprise risk

Risk Concepts

- Situation of Interest for Risk Assessment:

Areas where the undesirable events can occur:

- Manufacturing facility, mine, power plant, ...
- Transportation facility, rail, marine, pipeline, …
- Areas and markets where the company operates

Employees
Public
Environment
Plant Units/ Equipment
Property
Corporation
Shareholders
Society

- Questions we are trying to answer in Risk Management:

Risk Assessment

- What are the undesirable events that can occur at the risk source?
- What can their impacts be on the receptors? How likely are they?
- Should we try to eliminate or reduce the risk?

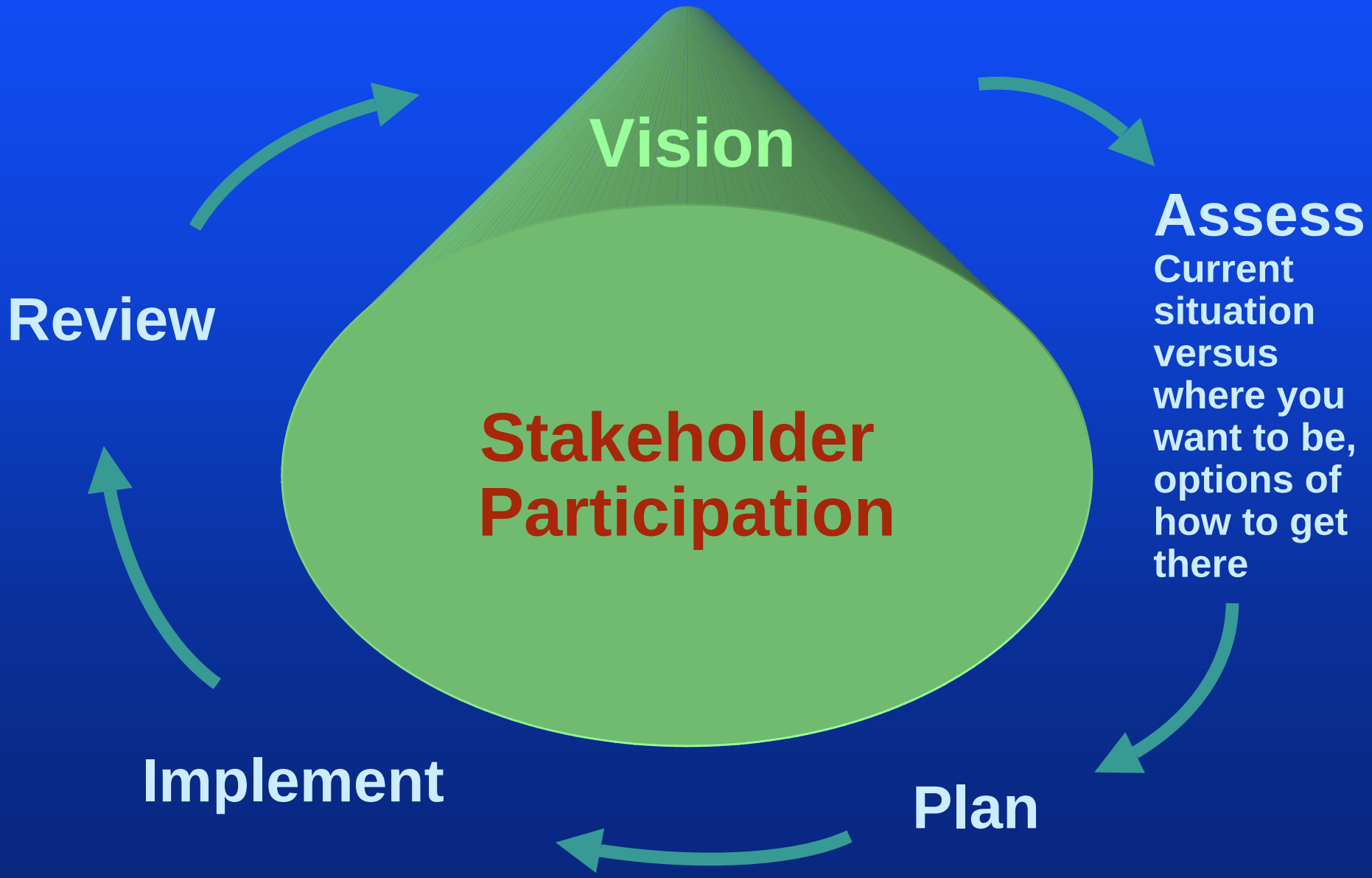
Risk Control

- If we should, how can we?

Management

- Process of analyzing business stakeholder needs, and taking steps to meet those needs by
  - Designing and implementing the necessary business processes (work flow),
  - Developing the resources to carry out these business processes, and
  - Organizing these resources.
- A major component of management is to eliminate the potential for disruption of work flow, or reduce this potential to acceptable levels
  - This we call risk management.

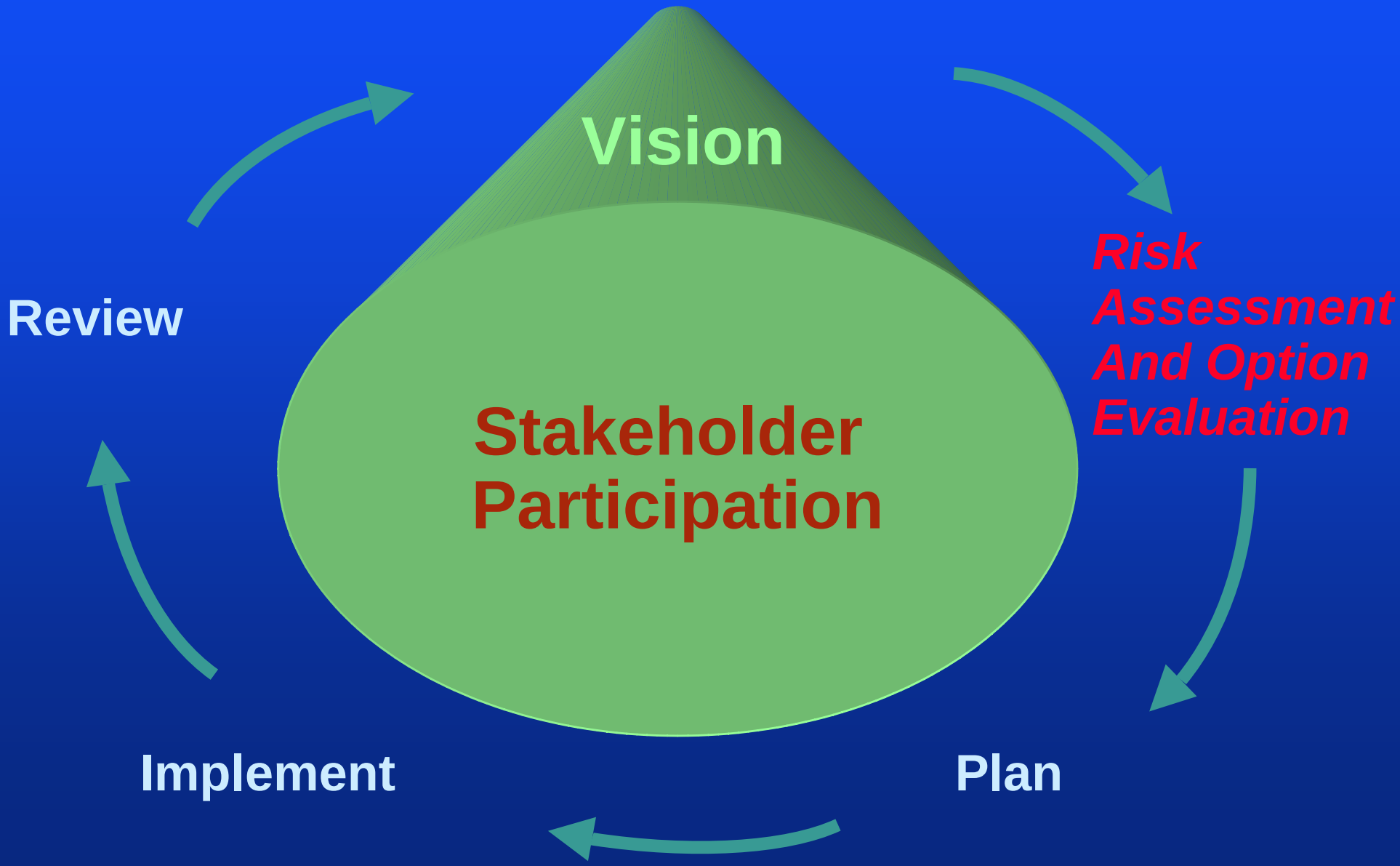
Management Process for Continual Improvement



Risk Management

- Process of analyzing exposure to loss and taking steps to eliminate the risk or reduce it to acceptable levels.
- ***Building safety into physical assets, as well as the way people think and work.***

Risk Management Process for Continual Improvement



Risk Management Process

Classical Management Process Steps
- *Vision: Set Policy and Direction*
- *Assess*
- *Plan*
- *Implement*
- *Review*

1. Initiation: Identify the Activity to be Managed, Identify the Stakeholders / Risk Receptors

2. System/ Scope Definition: Define Boundaries, Understand Needs of Stakeholders

Learning Loop

Continuous Improvement Loop

3. Risk Assessment

3a. Risk Analysis:
- Hazard Identification (at-risk behaviour and physical conditions)
- Consequence Analysis
- Likelihood Analysis
- Risk Estimation/ Ranking

3b. Risk Acceptability Evaluation: Do we need to reduce risk?

6. Learning: Broaden Scope, Increase Detail to Reduce Uncertainty

Cannot Decide

Need More Information

No

Yes

7. Stakeholder Participation
- Communicate Risks With Stakeholders
- Consider Stakeholder Needs/ Risks/ Costs/ Benefits in Decisions

4. Risk Control: Examine New/ Different Control Options
- Facility "Safety" Management (OHS. PSM,…)
- Land Use / Buffer Zones
- Incident Management / Emergency Response

- *Risk Avoidance*
- *Risk Transfer*
- *Risk Financing*
- *Risk Control*

5a. Plan Implementation of Activity/ New Controls

5b. Implement Activity/ New Controls

5c. Review: Monitor Controlled Risks/ Audit Implementation and Performance

The Challenge

RISK is seen by many people in terms of their own personal experiences…

The following quotation is one which exemplifies a typical approach to risk.

"…in all my experience, I have never been in an accident of any sort worth speaking about. I have seen but one vessel in distress in all my years at sea… I never saw a wreck and have never been wrecked, nor was I ever in any predicament that threatened to end in disaster of any sort."

Captain Edward J. Smith interviewed by the New York press, 1907.

On April 15, 1913, RMS Titanic sank with the loss of more than 1500 lives - one of which was its Captain - E.J.Smith.

Risk Concepts

- Formally, risk due to an “undesirable event”

  Risk = Likelihood of undesirable event
  x Consequence of that event

- Undesirable event
  - An event which has the potential for causing adverse effects on people, property/production or the environment
  - An event (or condition) that can result in reputational or material financial loss or prevent the organization from achieving its business objectives

Risk Concepts

- Examples of undesirable events
  - Equipment breakdown, collapse
  - Liquid spills, gas clouds, fires, explosions
  - Falls, falling objects, collisions
  - Environmental contamination as a result of short or long term releases
  - Loss of key personnel
  - Market collapse
  - Price/currency fluctuations
- We can provide a natural ***link*** between ***risk assessment*** and ***reliability and maintenance programs***, if we include in our list "equipment breakdown" even though in itself such an event may not have occupational, public, environmental or asset damage potential.

Formal Definition of Risk

Event Risk = Estimated likelihood of undesirable event X Estimated consequences of that event

- Units of risk depend on the choice of units for expressing the consequences
  - fatalities/year = events/year x fatalities/event
  - injuries/year = events/year x injuries/event
  - WCB cost $/year = events/year x WCB cost $/event
  - clean-up $/year = events/year x clean-up $/event
  - contaminated hectares/year = events/year x contaminated hectares/event
  - number of wildlife affected/year = events/year x number of wildlife affected/event
  - production loss $/year = events/year x $/event
  - property damage $/year = events/year x $/event
  - market share loss $/year = events/year x $/event
- Expressing risk is $ terms provides a natural progression to risk/ cost/ benefit analyses for decision-making purposes

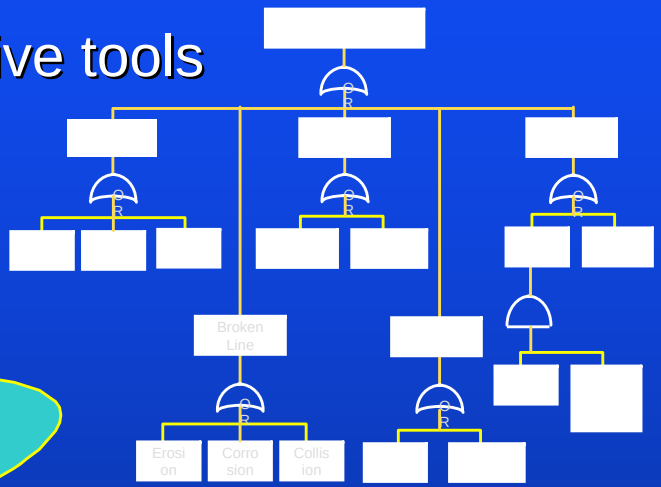
Requirements for Success …

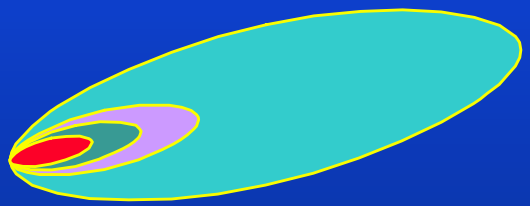
in Balancing the needs of Stakeholders and Achieving Superior Risk Management Performance

- Top-down commitment (Safety Culture)
- Bottom-up awareness (Safety Culture)
- Structure in the middle
- A risk management process well-understood by all
- Availability of a full range of risk assessment and risk/cost/benefit analysis tools of various sophistication
  - to determine the level of risk exposure using appropriate risk measurement parameters
  - to evaluate suitability of risk control actions
- Appropriate risk control strategies, and human and physical resources
- A company standard reflecting the values of the organization and the requirements that are asked of it

Integrated Risk Assessment Tools of Various Sophistication to Determine the Level of Risk Exposure

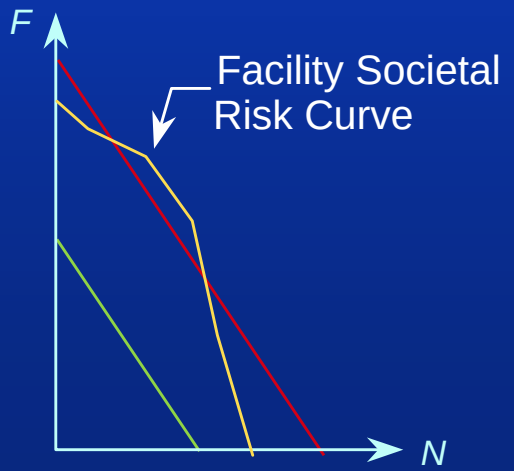
- Hierarchy of tools:
  - Qualitative / Semi-Quantitative / Quantitative tools
  - Screening Level Risk Assessment
  - HAZOP, FMEA, etc.
  - Job safety analysis
  - Fault trees, event trees
  - Consequence modeling
  - Financial representation of consequences





$$$

- Estimation of:
  - Individual risk
  - Societal risk
  - Facility risk
  - Integrated enterprise risk



Techniques for Risk Analysis

Risk analysis and evaluation can take place at different levels of detail. A hierarchy of risk analysis tools are available, depending on the requirements at hand:

- Qualitative Techniques (Screening Level Analysis, Checklists, What If, HAZOP, FMEA)
- Semi-Quantitative (Index/Matrix) Methods
- Quantitative Risk Analysis (QRA)

Similarities and Differences

Common Feature of the Various Approaches:

- The physical components of the system, the operation, and the factors influencing failure frequency must be understood.

Differences Between the Various Approaches:

- Checklists, etc., provide only qualitative information about a system, and help to identify hazards.
- The index/matrix techniques provide semi-quantitative information. The index values are dimensionless, and do not have any meaning other than within that particular indexing system.
- The QRA will provide quantitative information in commonly understood units. Therefore, it is possible to make inter-industry comparisons and comparisons against benchmark acceptability criteria, and quantify benefits against cost of risk reduction measures.

Progression From Simpler to More Complex Techniques

We do not have the time and resources to use the most complex techniques, nor should we try to use the most complex techniques for every problem at hand

- During the implementation stages of a risk management program, or for any new activity or project, we should start by carrying out a screening level assessment.
- Screening level techniques provide us with information on
  - Whether we can act without further study and analysis
  - What type of further analysis would be warranted (qualitative/ quantitative)
- If high-risk areas as identified by a screening level approach are related to chemical processes, a HAZOP may be suitable as the next level of detailed study for those areas, to understand how a process can fail and to develop safeguards that would help minimize the likelihood or severity of such failures
- For complex equipment, a FMEA may be suitable

Typical Output from a Qualitative Risk Analysis: List of Hazardous Events and Their Risk Ranking

					Public			Env.			Empl.			Prod.			Cap.Equ.			Mark.Shr				
Process Section	Process Section	Hazard Id. No.	Hazardous Events	Cause(s)	Frequency	Consequences	Risk	Frequency	Consequences	Risk	Frequency	Consequences	Risk	Frequency	Consequences	Risk	Frequency	Consequences	Risk	Frequency	Consequences	Risk	Safe-guards	Actions
1	Natural Gas Supply	1	Fireball and Jet flame from transmission line	Underground pipeline rupture due to corrosion, third party damage with ignition of released gas	1	4	*L*	2	2	*VL*	2	4	*M*	2	3	*L*	2	3	*L*	1	1	*VL*	Work permit system; cathodic protection	
		1	Fireball and Jet flame from transmission line	Abovegroud pipeline rupture due to corrosion, third party damage, collision with ignition of gas	1	4	*L*	2	2	*VL*	3	4	*H*	2	3	*L*	2	3	*L*	1	2	*VL*	Cathodic protection	Install collision protection at main gas inlet to plant process area. Improve line labelling and develop unique colour code for piping.
		1	Gas release (with traces of H2S)	Upstream failure to treat gas at source	1	2	*VL*	1	2	*VL*	1	2	*VL*	1	3	*VL*	1	1	*VL*	1	1	*VL*		Check possibility of H2S in gas supply
2	Process Steam Supply	2	Firebox explosion	Insufficient purge and failure of burner management system	2	1	*VL*	2	1	*VL*	2	4	*M*	2	2	*VL*	2	2	*VL*	2	1	*VL*	Burner management system (fireeye, shut-off interlocks)	
		2	Steam drum BLEVE	Material failure	1	1	*VL*	1	1	*VL*	1	3	*VL*	1	2	*VL*	1	2	*VL*	1	1	*VL*	Inspections before installations; NDT testing	

Progression from Qualitative to Quantitative Analysis

- A Qualitative analysis generally:
  - is conducted by walk-though inspections and in sit-down team sessions,
  - is relatively quick,
  - does not require high-level technical and scientific skills,
  - is based on the personal knowledge and experience of the people in the team.
- As such, the assignment of undesirable events into frequency/consequence classes may have large uncertainties.
- For some events of interest (e.g., high risk, high consequence, high mitigation cost), it may be desirable to understand their frequencies and/or consequences with a higher accuracy than would be possible with a qualitative analysis based on personal knowledge.

Progression from Qualitative to Quantitative Analysis

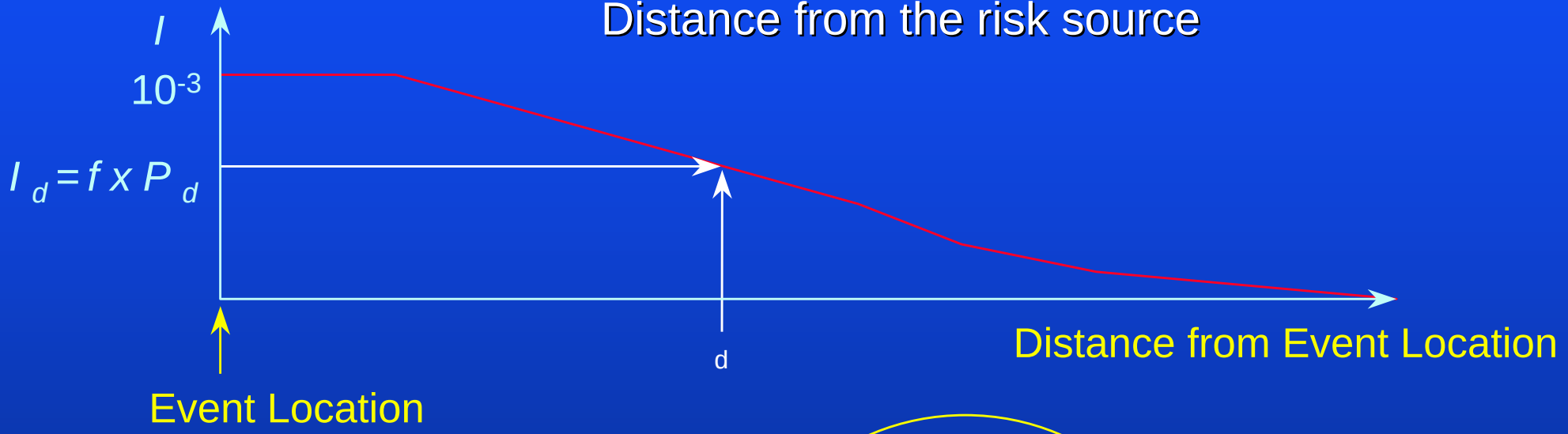
- For events where higher accuracy is desirable, well-established quantitative techniques are available for improving the accuracy of the analysis.
- For such events (especially those with off-site consequences):
  - estimate their frequency using established techniques (e.g., fault trees, event trees).
  - estimate hazard levels as a function of distance from event location using mathematical models (e.g., dispersion models for toxic gases or vapours).

Quantitative Analysis

- This information is used to confirm or correct the earlier qualitative assignments and ranking, and to feed into emergency response plans.
- Once event risks are quantified, this information will also lend itself to:
  - making risk/ cost/ benefit analyses, and to
  - estimation of total facility risk for:
    - comparison against acceptability guidelines, and/or for
    - understanding total financial risk exposure of projects or facilities.

Presentation of Risk
Individual Risk

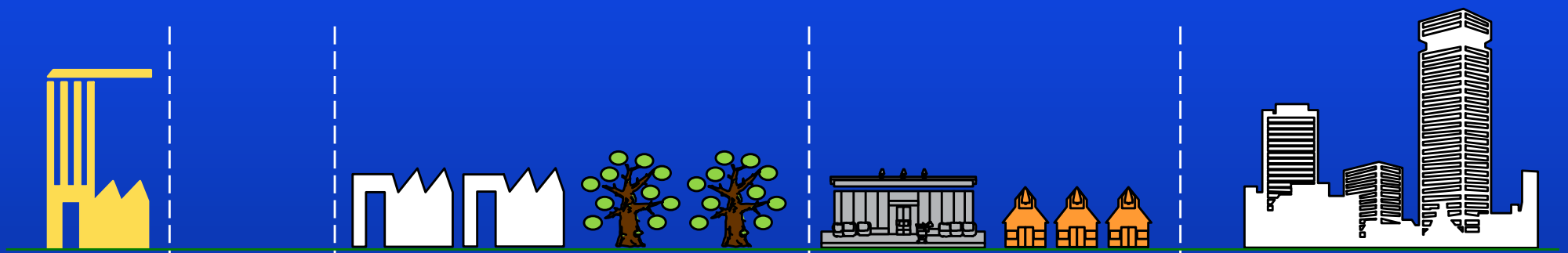
- Individual Risk Profile: Graph of Individual Risk as a function of Distance from the risk source



- Individual Risk Contours (for non-directional events, viewed from above; for directional events, the contours would not be circular)

E.g. Risk Acceptability Criteria for Land-use Planning

Annual Individual Risk
(chance of fatality per year)



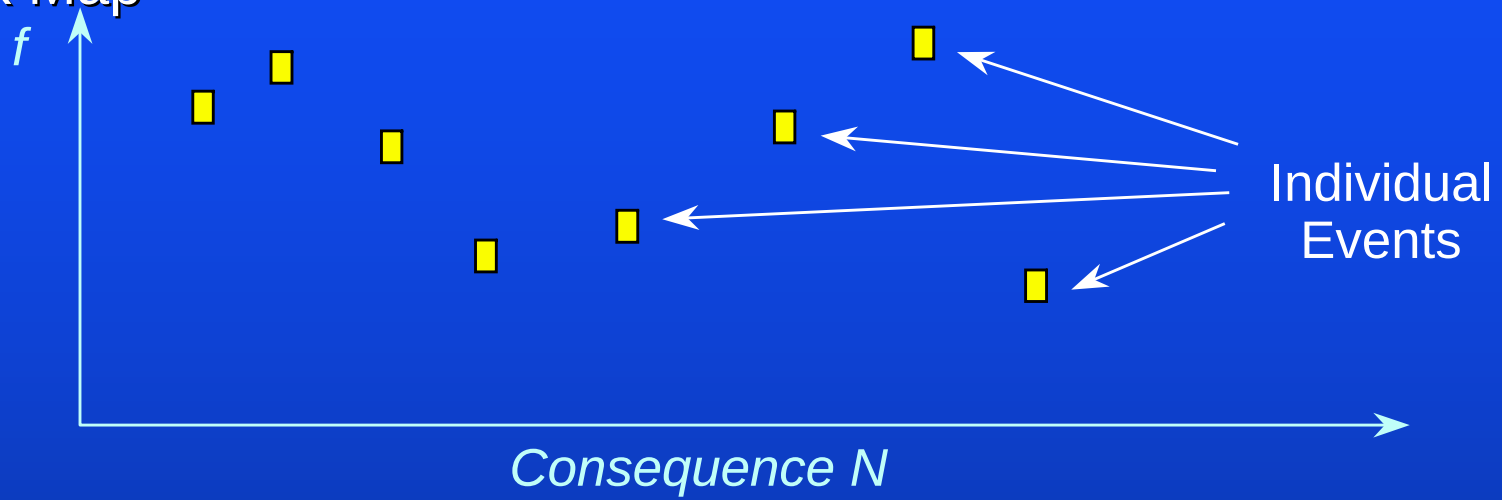
Risk source	No other land use	Manufacturing, warehouses, open space (parkland, golf courses, etc.)	Commercial, offices, low-density residential	All other uses including institutions, high-density residential, etc.

Allowable Land Uses

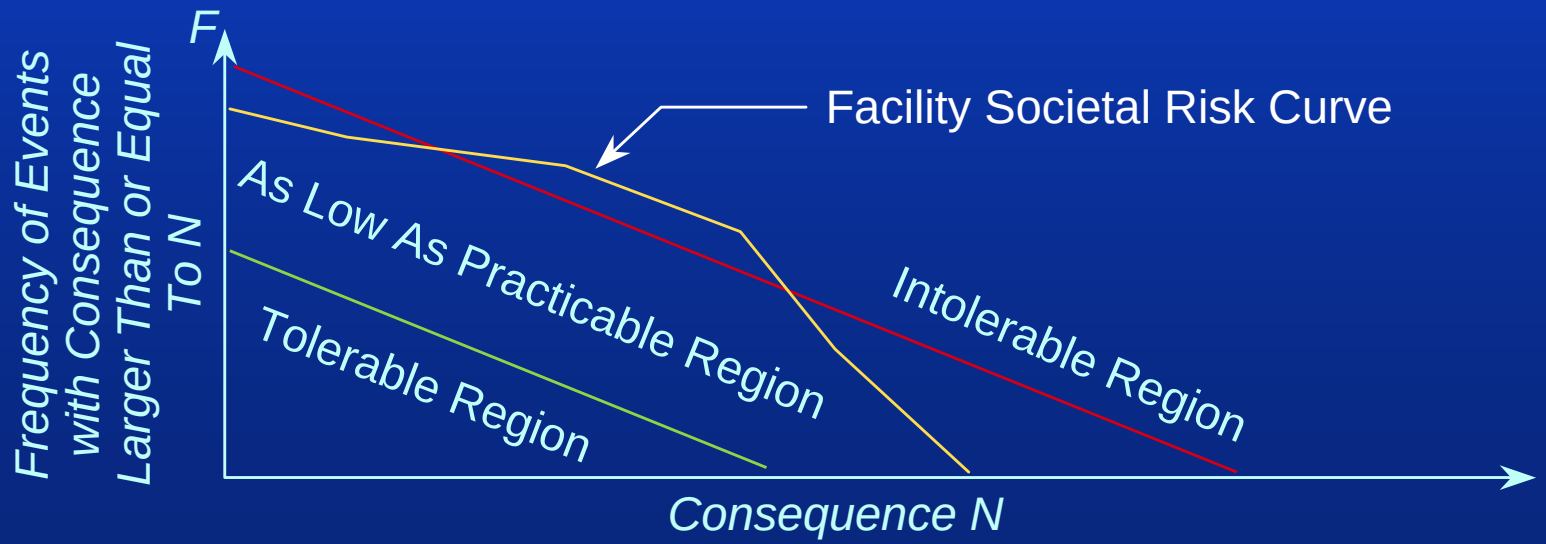
Presentation of Risk

Societal Risk

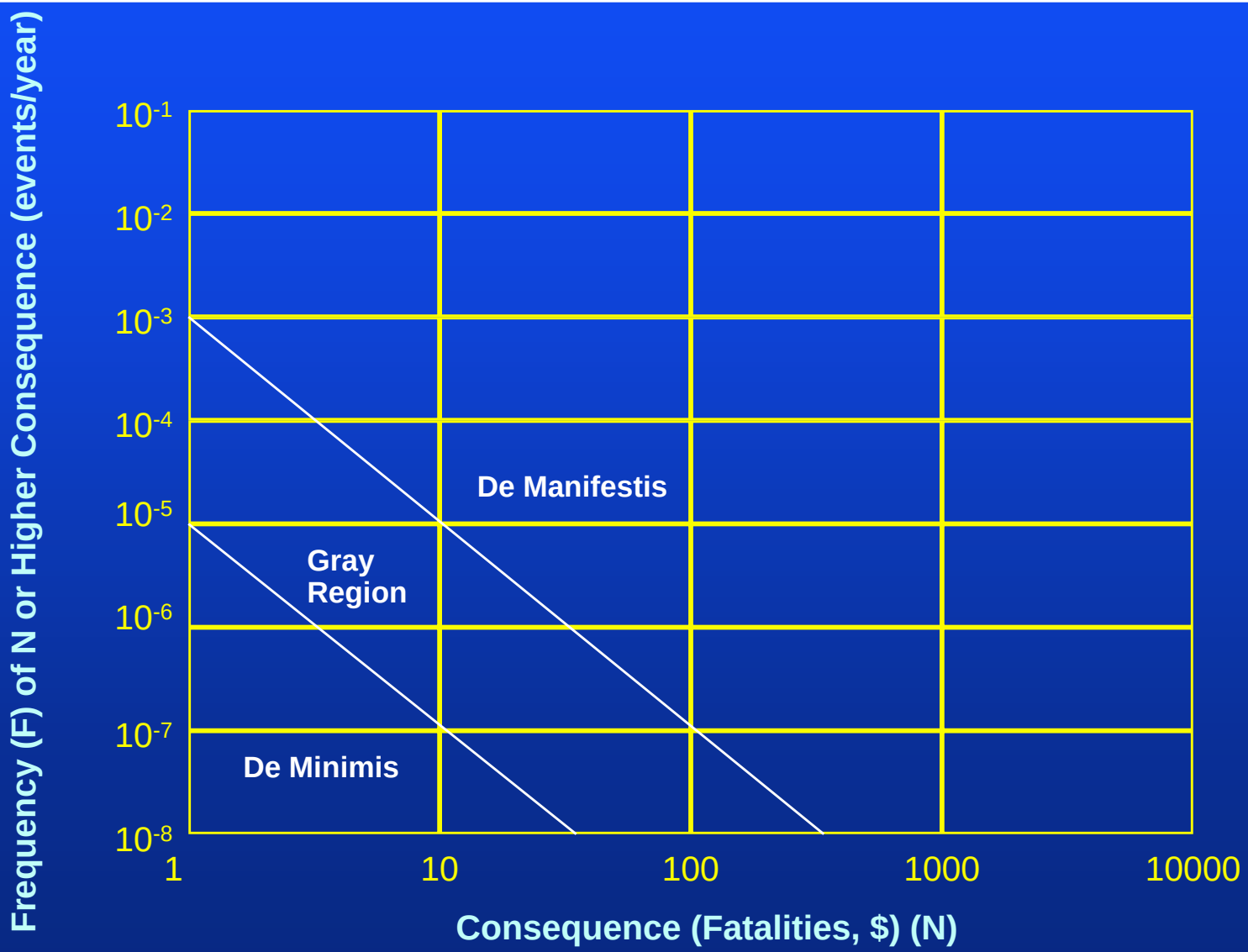
- Loss/Risk Map



- Loss/Risk Profile (Complementary Cumulative Distribution Function or FN Curve)



Example Societal Risk Guidelines



Why Bother...?

- Not only do we want to avoid any human suffering, and environmental degradation, but also:

"Safety" issues present significant risks to business performance.

Why Bother...?

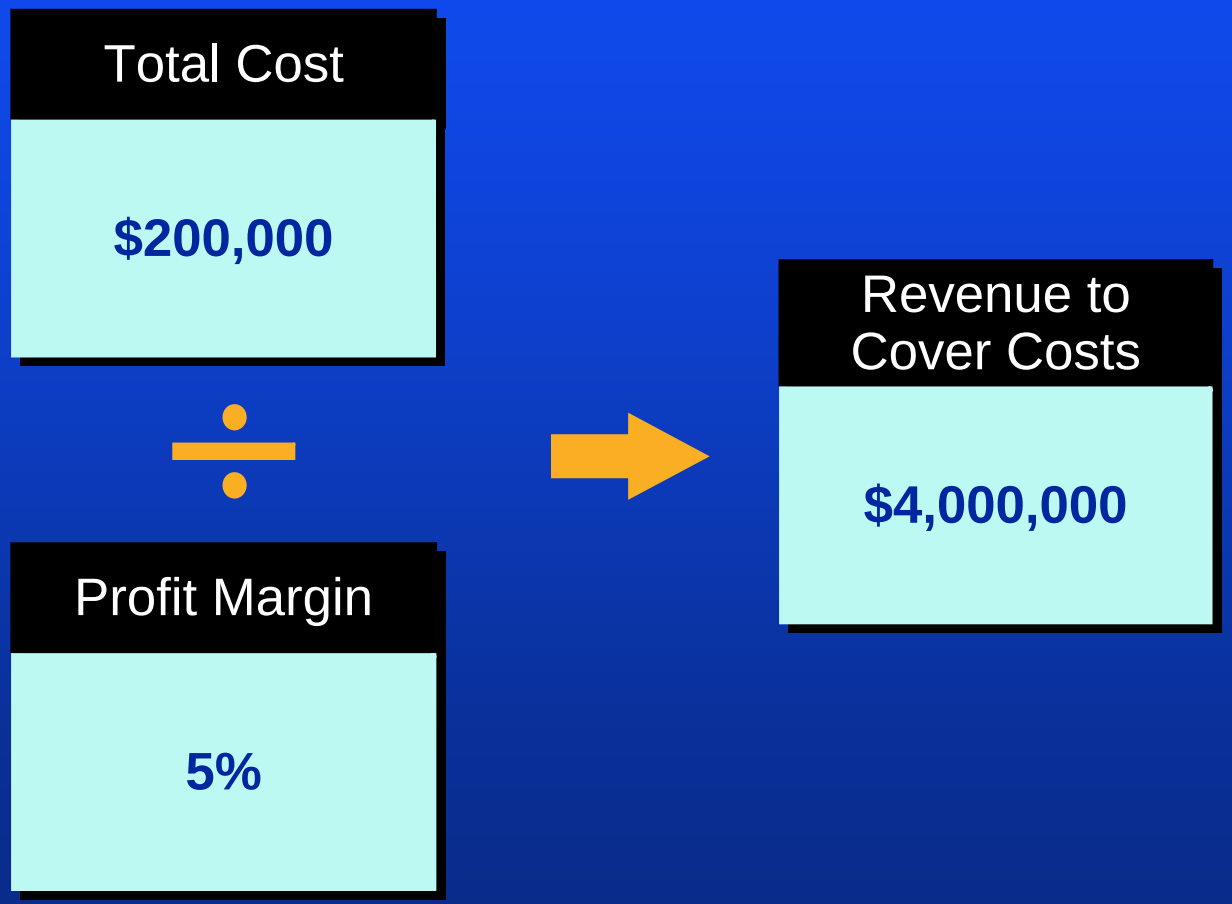
- The potential impact on the profit and loss of an organization can be significant.

Undesirable Event

The Cost Iceberg

Why Bother...?

- The knock on impact for revenue generation can be sizable.



- How easily can your business generate this extra revenue?