

# BowTie Analysis

A qualitative risk analysis methodology



**VAULT**  
MINERALS

Team Based Training Day



PetroMarine Risk Consultants



Started with bowtie analysis in 2006 and have continued to develop and teach robust qualitative bowtie analysis



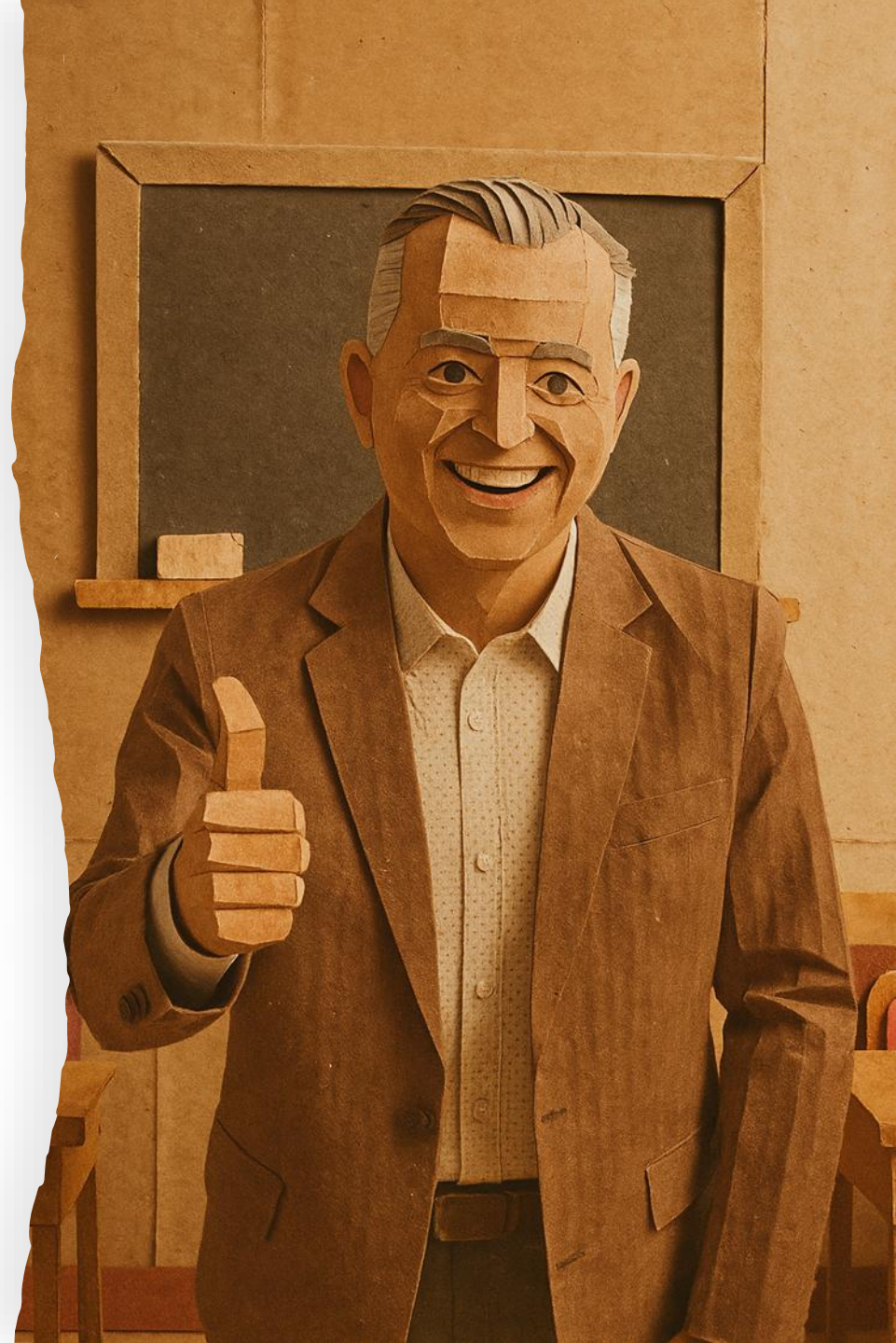
19 years of safety and risk consulting in major hazard industries and facility safety cases around the world



Four years of academic study and research relating to risk management with a specialisation in qualitative bowtie analysis

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**BowTieXP**  
Advanced Practitioner  
Official Certified Partner



# Welcome and Introductions

- What is your experience with BowTie analysis?
- Where and how will you be using BowTie analysis?
- Do you have any specific expectations or concerns?



# Schedule and Agenda

08:00 : Welcome and introductions

10:30 : Morning break (15 minutes)

12:00 : Lunch break (30 minutes)

14:30 : Afternoon break (15 minutes)

16:30 : Conclusion

- Risk management and safety culture foundation
- Risk modelling foundation
- Bowtie modelling methodology (with exercises)
- Bowtie control methodology (with exercises)
- Final QandA and practical application



# Learning Outcomes

- Understand the theory and underlying risk management principles related to the BowTie analysis methodology
- Understand how to prepare for and facilitate effective BowTie analysis
- Understand the good practices to apply when conducting BowTie analysis

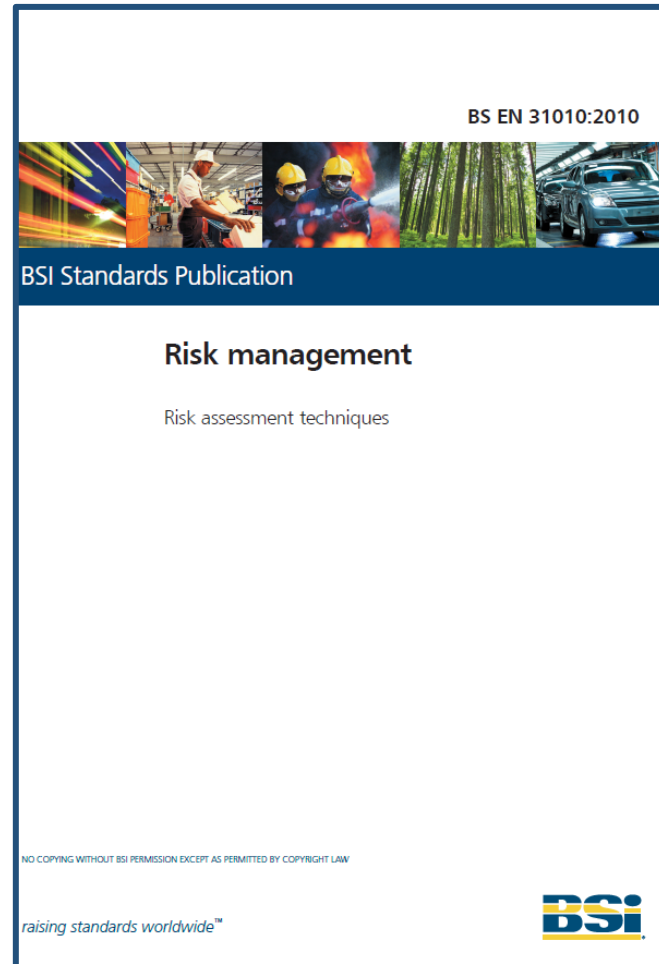
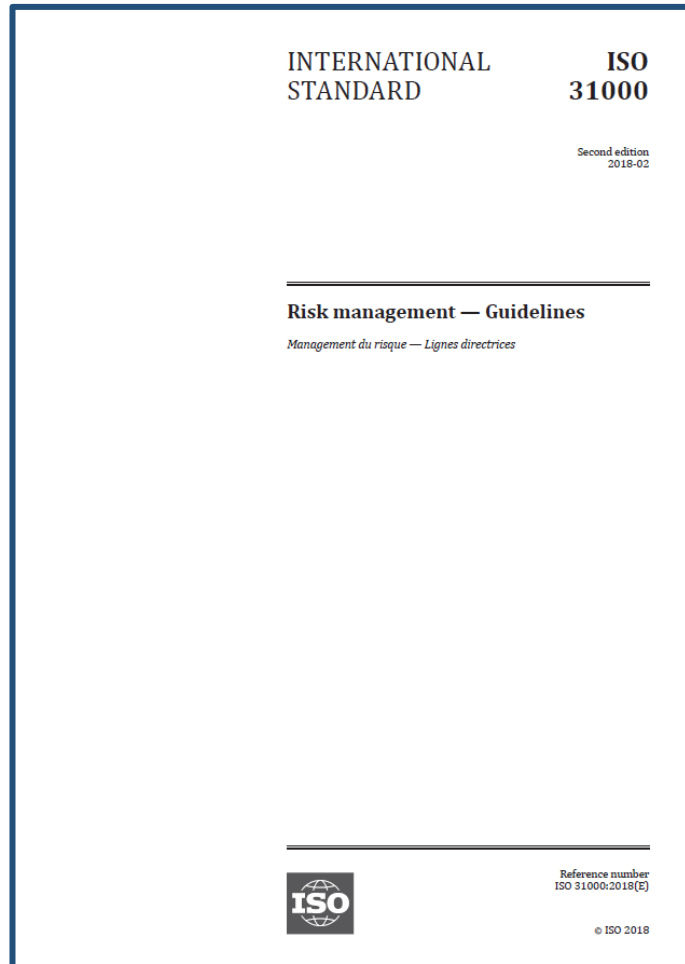


# Risk Management

A standards-based approach is the only way forward



# ISO 31000 and 31010



BS EN 31010:2010  
31010 © IEC:2009

– 66 –

Figure B.8 – Example bow tie diagram for unwanted consequences

IEC 2009/09

**B.21.6 Strengths and limitations**

Strengths of bow tie analysis:

- it is simple to understand and gives a clear pictorial representation of the problem;
- it focuses attention on controls which are supposed to be in place for both prevention and mitigation and their effectiveness;
- it can be used for desirable consequences;
- it does not need a high level of expertise to use.

Limitations include:

- it cannot depict where multiple causes occur simultaneously to cause the consequences (i.e. where there are AND gates in a fault tree depicting the left-hand side of the bow);
- it may over-simplify complex situations, particularly where quantification is attempted.

**B.22 Reliability centred maintenance**

**B.22.1 Overview**

Reliability centred maintenance (RCM) is a method to identify the policies that should be implemented to manage failures so as to efficiently and effectively achieve the required safety, availability and economy of operation for all types of equipment.

RCM is now a proven and accepted methodology used in a wide range of industries.

RCM provides a decision process to identify applicable and effective preventive maintenance requirements for equipment in accordance with the safety, operational and economic consequences of identifiable failures, and the degradation mechanism responsible for those failures. The end result of working through the process is a judgment as to the necessity of performing a maintenance task or other action such as operational changes. Details regarding the use and application of RCM are provided in IEC 60300-3-11.

# Terminology is Critical

cause precondition reduction  
prevention likelihood  
elimination control top event  
threat frequency escalation  
probability exposure ALARP cause  
risk consequence barrier latent failure tolerable  
recovery outcome safeguard hazard  
mitigation active failure

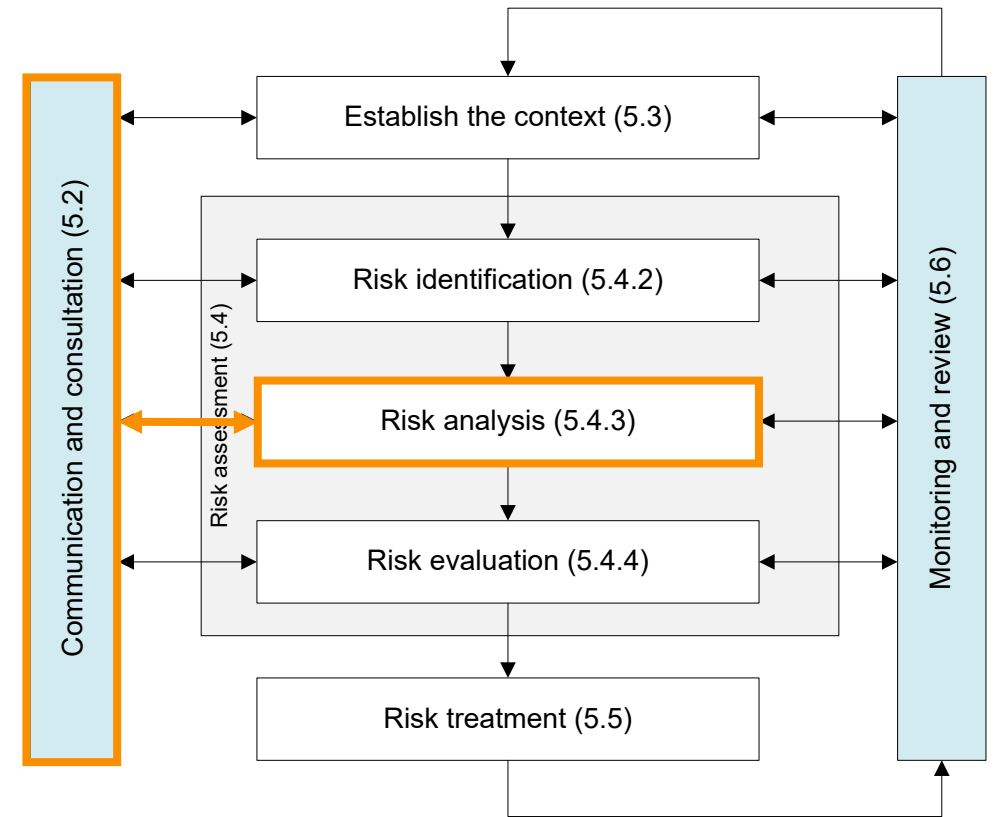


# Risk Management

- Risk management system
  - Risk management policy
  - Risk management framework
  - Risk management process

# Risk Management Process

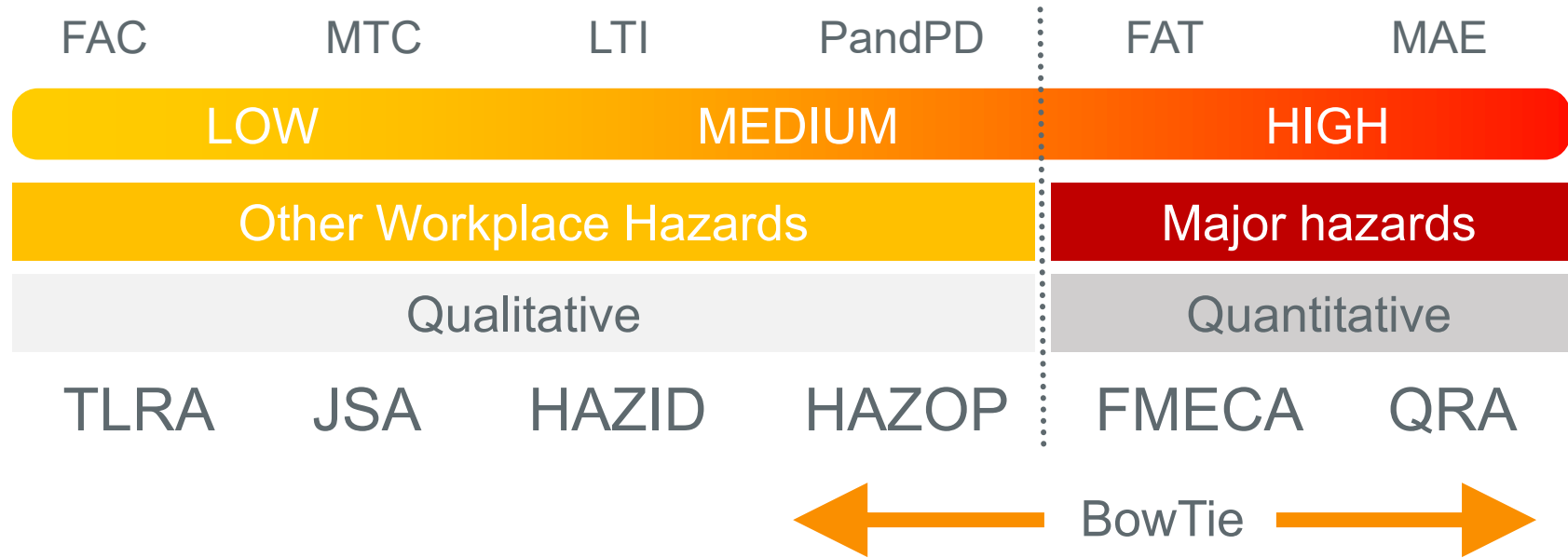
- Risk assessment
  - Risk identification
  - Risk analysis
  - Risk evaluation



BowTie analysis is a “risk analysis” technique, and excels at risk communication



# Choosing the Right Tool



BowTie analysis is not always the right tool for the job



# Safety Culture and Risk

From the pathological to generative organisation



# Safety Culture Typology

Pathological

Who cares about safety, as long as we are not caught

Reactive

Safety is important; we do a lot when we have an accident

Calculative

We have systems in place to manage all hazards

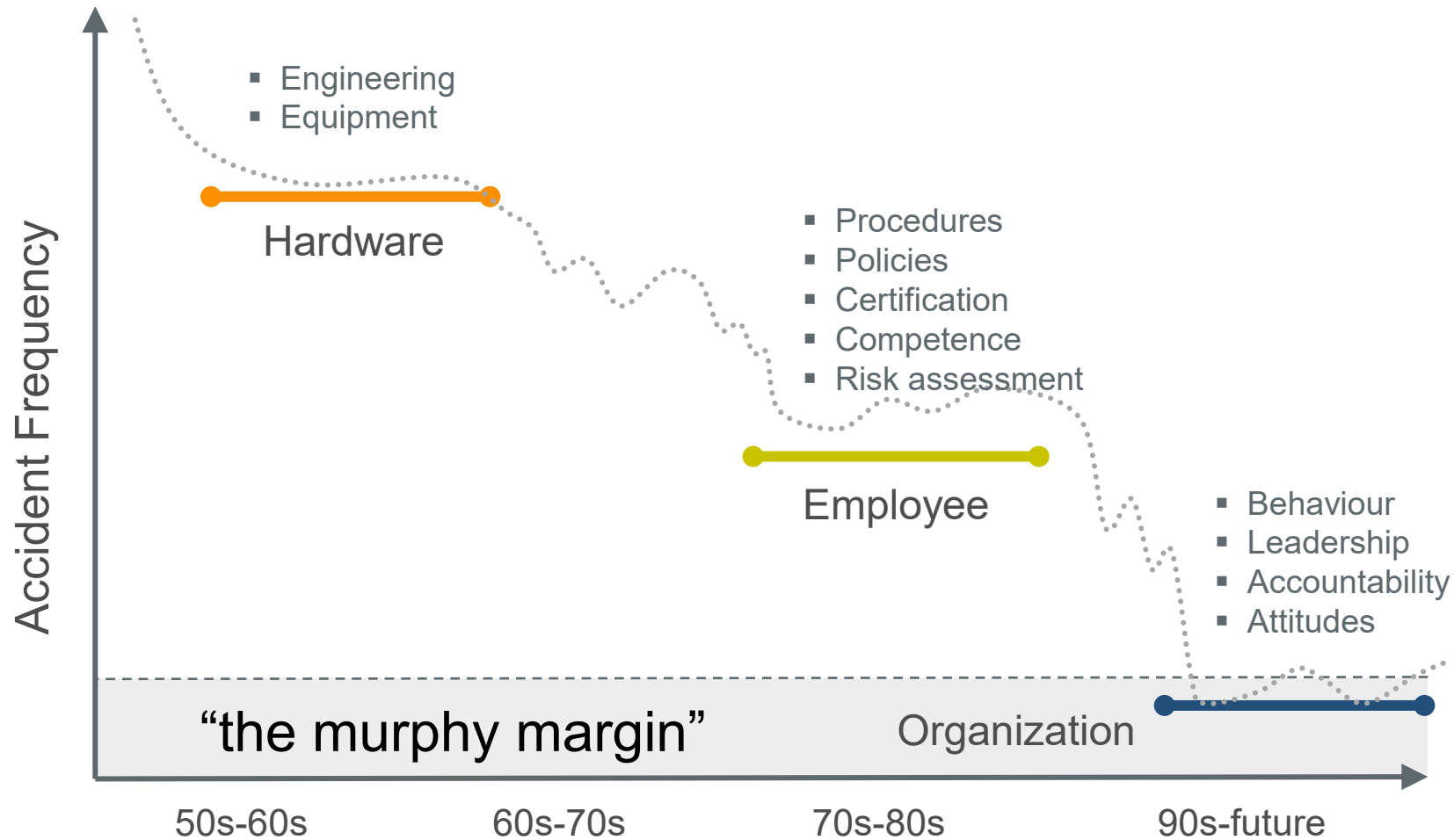
Proactive

We try to anticipate safety problems before they arise

Generative

HSE is how we do business around here

# Safety Culture Development



# Fighting the Murphy Margin

Creeping Entropy

Normalization

Routinization

Intrinsic Hazard

Murphy's Law

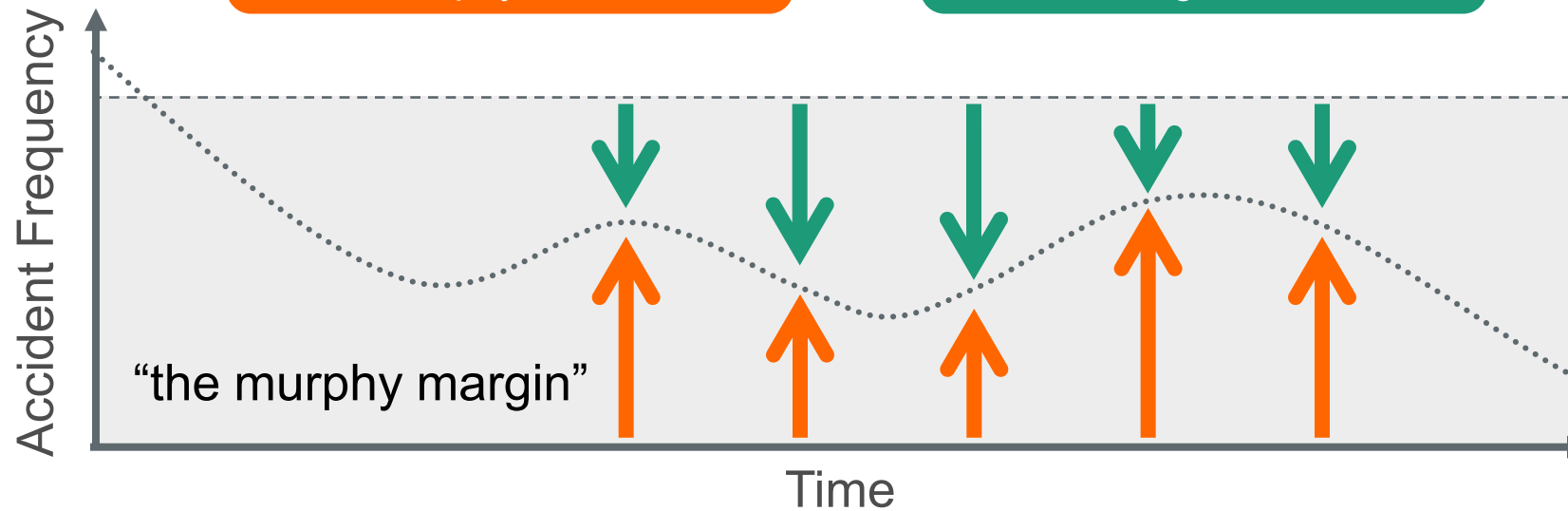
Open Reporting

No Blame Culture

Incident Investigation

Unsafe Act Awareness

Auditing Controls



# Risk Modelling

A comparison of similar modelling techniques



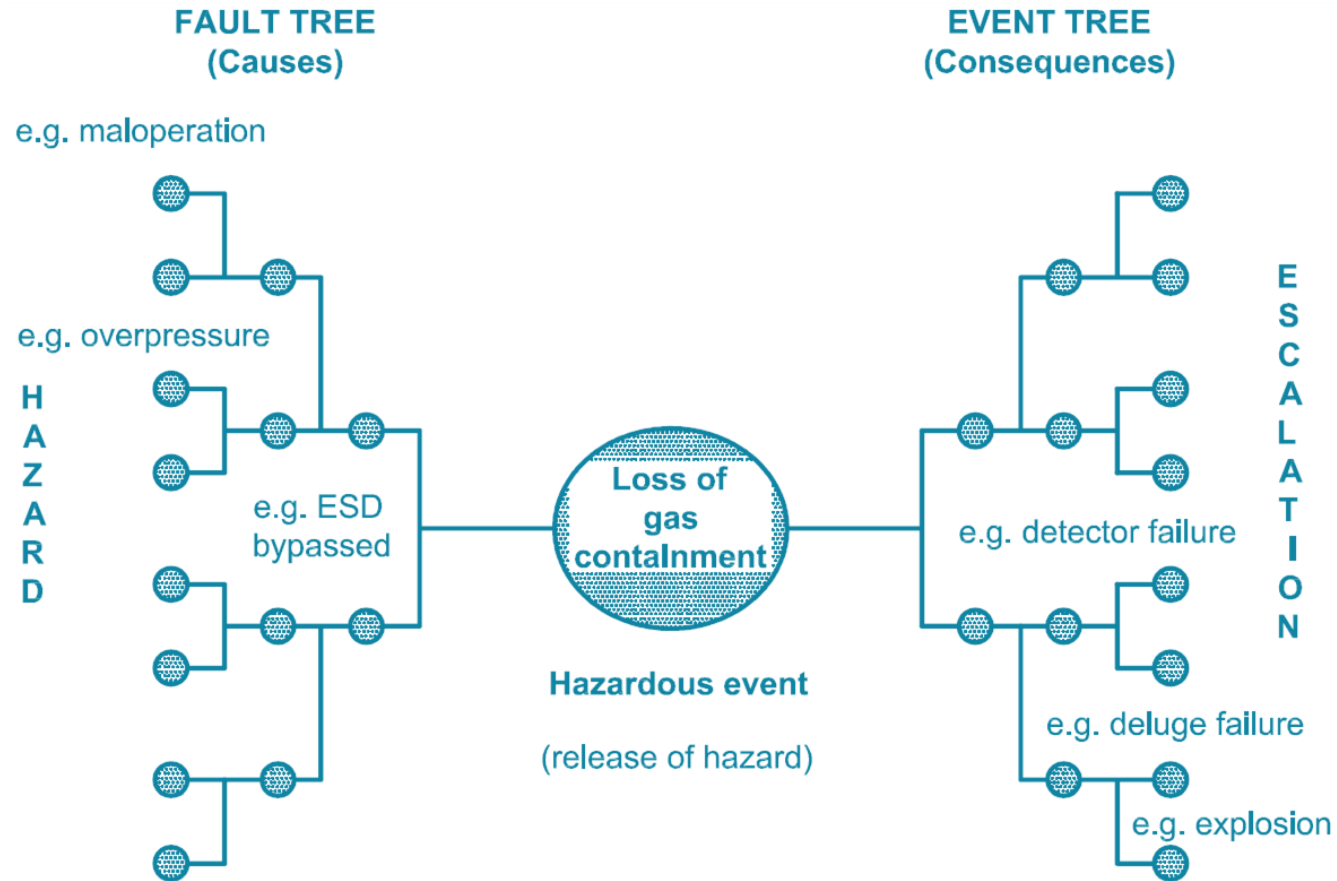


## *All models are wrong, but some are useful*

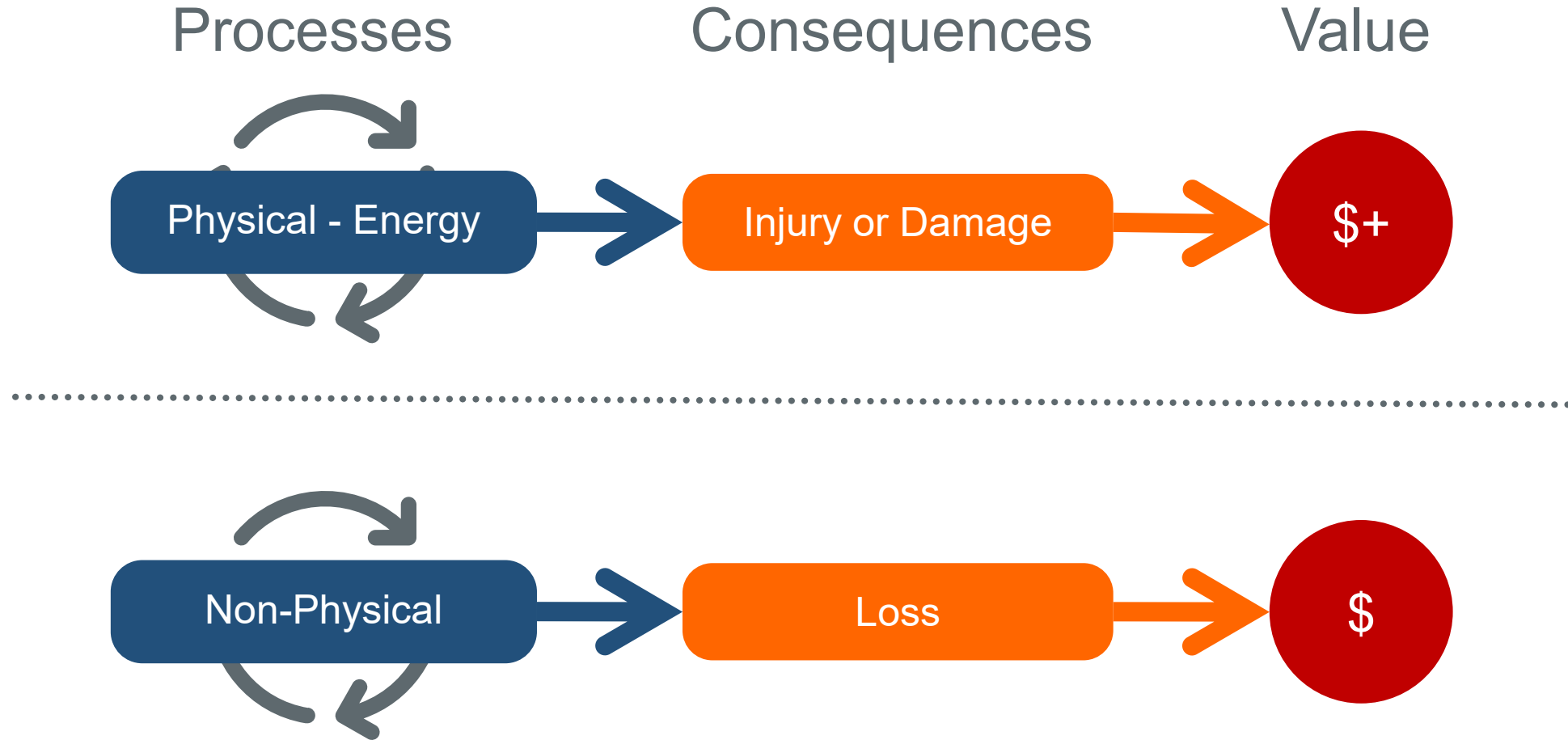
*Since all models are wrong, the scientist cannot obtain a “correct” one by excessive elaboration. On the contrary following William of Occam, he should **seek an economical description of natural phenomena.***

*Since all models are wrong, the scientist must **be alert to what is importantly wrong.** It is inappropriate to be concerned about safety from mice when there are tigers abroad.*

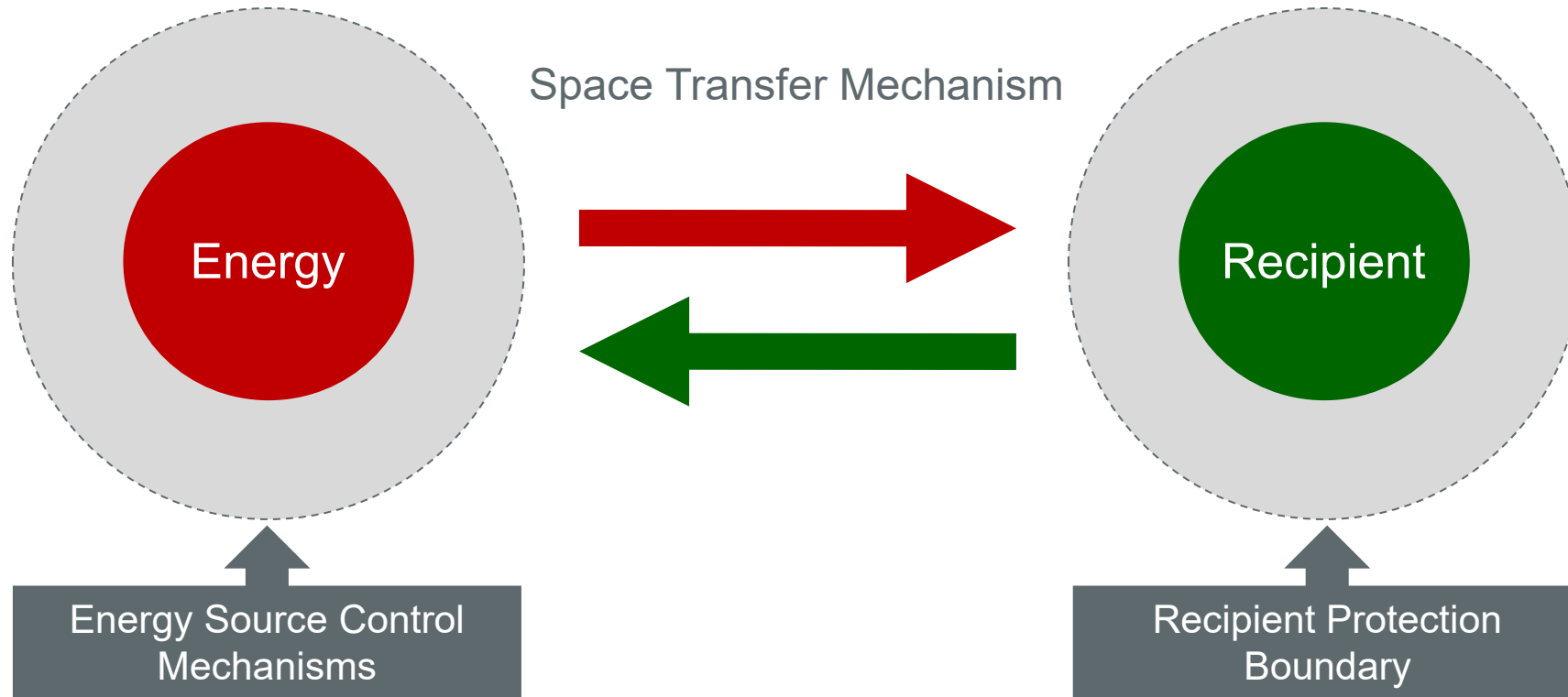
# Combined Fault Tree and Event Tree



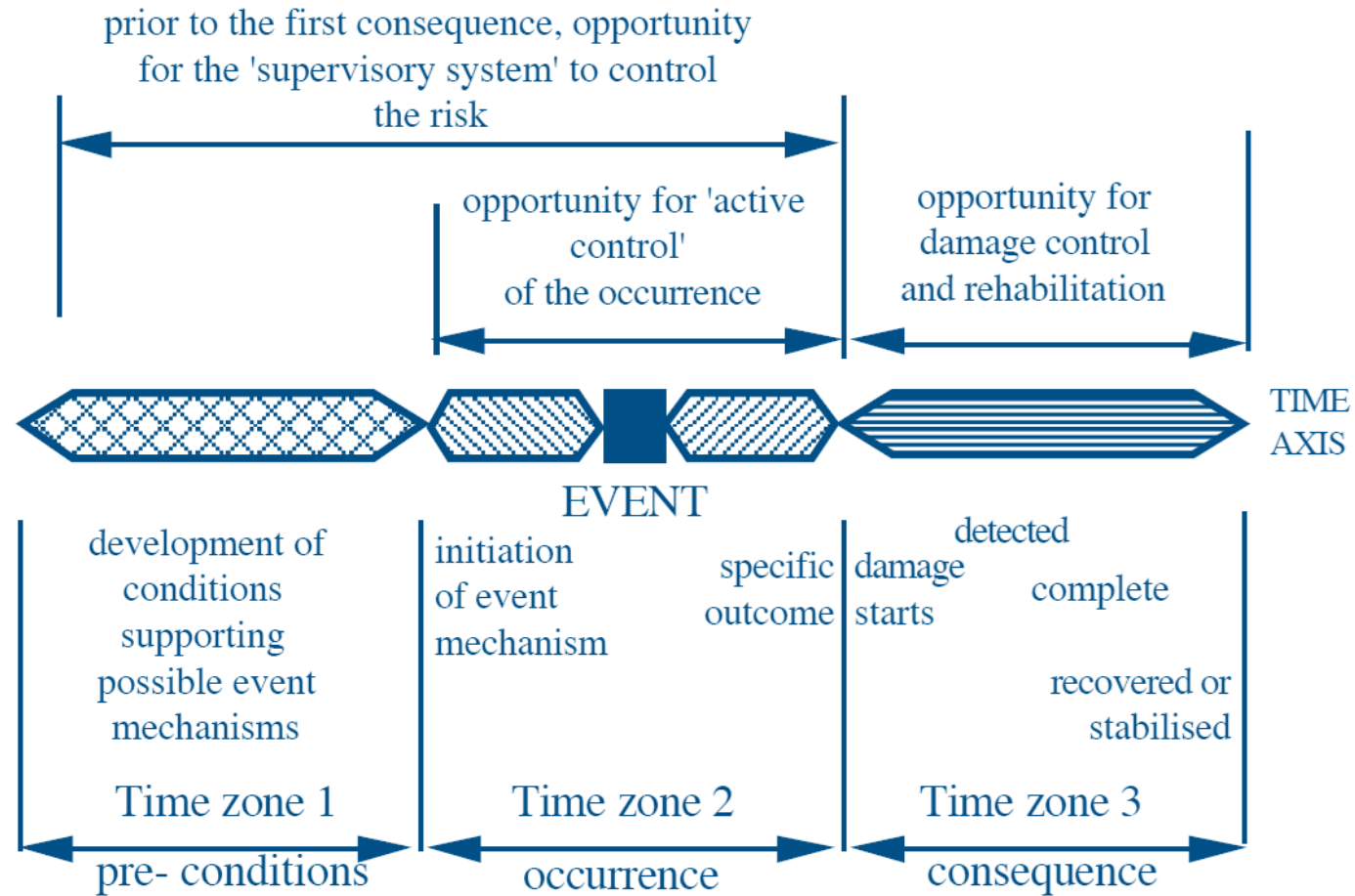
# Process of Injury, Damage and Loss



# Extended Energy Damage Model



# Generalized Time Sequence Model



Qualitative BowTie analysis employs an **epidemiological** modelling approach which requires **high information complexity** arising from barrier analysis

Model type	Principle	Analysis goals
Sequential	Specific causes and well-defined links	Eliminate or contain causes
<b>Epidemiological</b>	<i>Carriers, barriers, and latent conditions</i>	<i>Make defences and barriers stronger</i>
Systemic	Tight couplings and complex interactions	Monitor and control performance variability



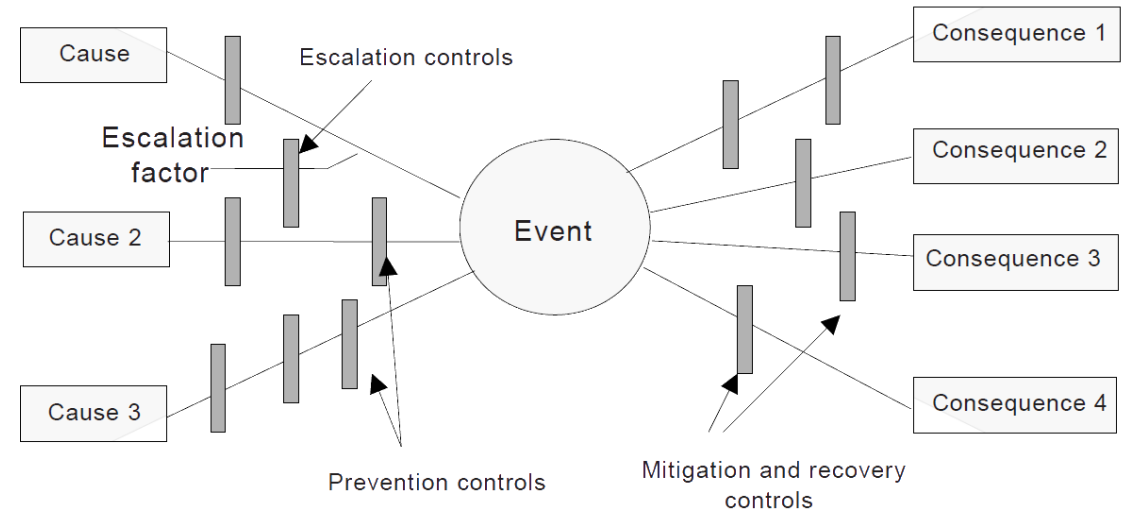
# Bowtie Analysis

The methodology and some good practices





*Beware the  
deception of  
simplicity*



	No.	Analytical Element	Common Analytical Element Synonyms
Model	1	Hazard	<i>threat energy</i>
	2	Top Event	<i>hazardous event</i>
	3	Causes	<i>mechanisms, threats</i>
	4	Outcomes	<i>consequences</i>
Control	5	Controls	<i>barriers, safeguards, defences, mitigations</i>
	6	Defeating Factors	<i>escalation factors, preconditions, active failures</i>
	7	Defeating Factor Controls	<i>escalation factor controls</i>

# BowTie Analysis Process

## Modelling Phase

- Step 1 : Hazards
- Step 2 : Top events
- Step 3 : Outcomes
- Step 4 : Causes

## Control Phase

- Step 5 : Cause controls
- Step 6 : Outcome controls
- Step 7 : Defeating factors
- Step 8 : Defeating factor controls

BowTie analysis is a semi-linear, segmented, and iterative process



# Modelling Phase

Understanding the process of injury, loss and damage



# Step 1 - Hazards

*Anything which is a potential source of injury, loss, or damage*

*A source of potential harm*

ASNZ 4360 : Risk Management

*Potential source of harm*

ISO/IEC Guide 73: Risk Management - Vocabulary



# How do Hazards Cause Harm

## Energy

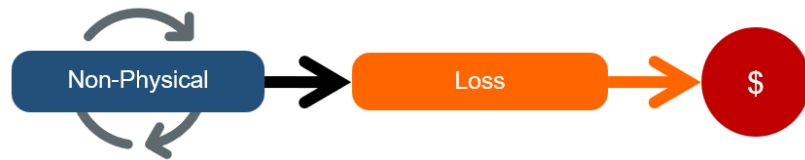


Energy is the capacity of a physical system to perform work. We use energy in many forms as a 'normal part of our business'. this energy exists in many forms.

- Potential
- Kinetic
- Flowing mechanical
- Acoustic / vibrating
- Electrical
- Ionising radiation
- Thermal
- Chemical
- Micro-biological
- Muscular

# How do Hazards Cause Harm

## Non-Energy

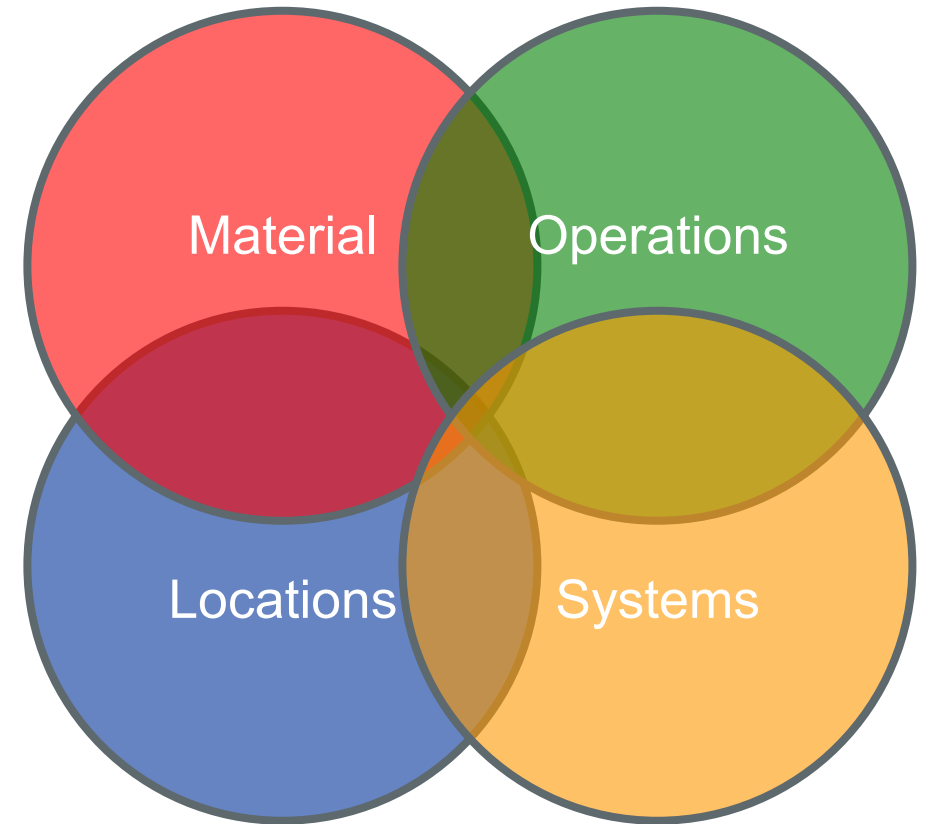


- Financial
- Sociological
- Psychological
- Emotional
- Moral
- Political

Not all hazards involve physical or energy processes. Depending on the application of the technique, BowTie can also be applied to other non-physical scenarios.

# How do You Identify Hazards

- Previous risk analysis
- Incidents and accidents
- Standards and guidelines
- Legislation and regulations
- Experience and judgment
- Industry checklists



BowTie analysis is not a hazard identification (HAZID) technique



# Hazards Exist in Normal Business



Flammable  
Materials



Heavy  
Vehicles



Helicopter  
Transportation

In BowTie analysis, hazards are a part of normal business and are not what you are trying to eliminate



# Using Hazard Guidewords



- 1 Include the type of **energy**
- 2 Use the commonly accepted **name**
- 3 Describe it in the controlled / good **state**
- 4 Provide situational **context**

Use both formal and simple hazard definition statements



# Hazard Guidewords Example



## Formal Hazard Definition

Chemical bonding energy within hydrocarbon gas and liquid, contained within the geological formation, during offshore drilling operations

## Simple Hazard Definition

Hydrocarbons in the formation



# Generic and Specific Hazards

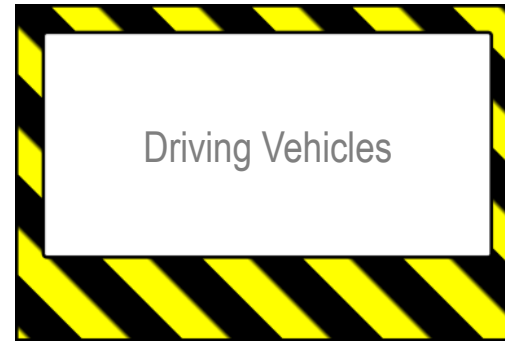
Generic



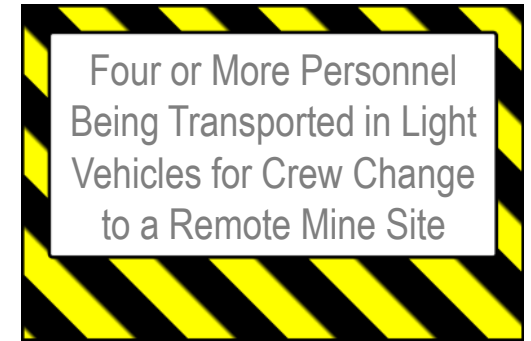
Specific



Generic



Specific



Using 'generic' hazards saves time and effort, but results in a lot of generalizations when it comes to causes, outcomes, and especially controls. The more specific you make the hazard the more 'accurate' the analysis will be, but you will have a lot more BowTie models to develop.

# Hazard Good Practices

- Don't use BowTie analysis for hazard identification
- Hazards are typically a source of energy
- Hazards are a part of normal business
- Hazards exist, they do not 'happen'
- Use guidewords to define and scope the hazards
- Make hazards as specific as is practicable

Use these good practices when doing your BowTie analysis





Identify the hazard(s) that are associated with the transportation of people to an offshore facility which can result in multiple fatalities



# Step 2 - Top Events

*The point in time when control is lost over the potentially damaging properties of a hazard*

*A particular hazardous event considered in the development of fault and event trees*

ISO/IEC Guide 73: Risk Management - Vocabulary



# How to Identify Top Events

What states, properties, or abilities does the system rely on for the control of the potentially damaging properties of the hazard energy?

The top event(s) will be the failure or loss of these system states, properties or abilities.

# Top Event Example

## Formal Top Event Definition

The point in time when hydrocarbon liquid phase oil containment is lost from the well at surface, resulting in a large-scale unignited release onto the facility topsides



## Simple Top Event Definition

Loss of hydrocarbon containment

# General Purpose Top Events

- Loss of {insert material name here} containment
- Loss of {insert safe operating parameter here} regulation
- Loss of physical separation
- Loss of navigational control
- Loss of stability
- Loss of speed regulation
- Loss of connection
- Loss of suspension support

# Top Event Good Practices

- Top means first, not big or important
- Top events are not disasters or cause harm
- Hazards can have multiple top events
- Top events usually involve a change of 'state'
- Define the top event with detailed guidewords

Use these good practices when doing your BowTie analysis





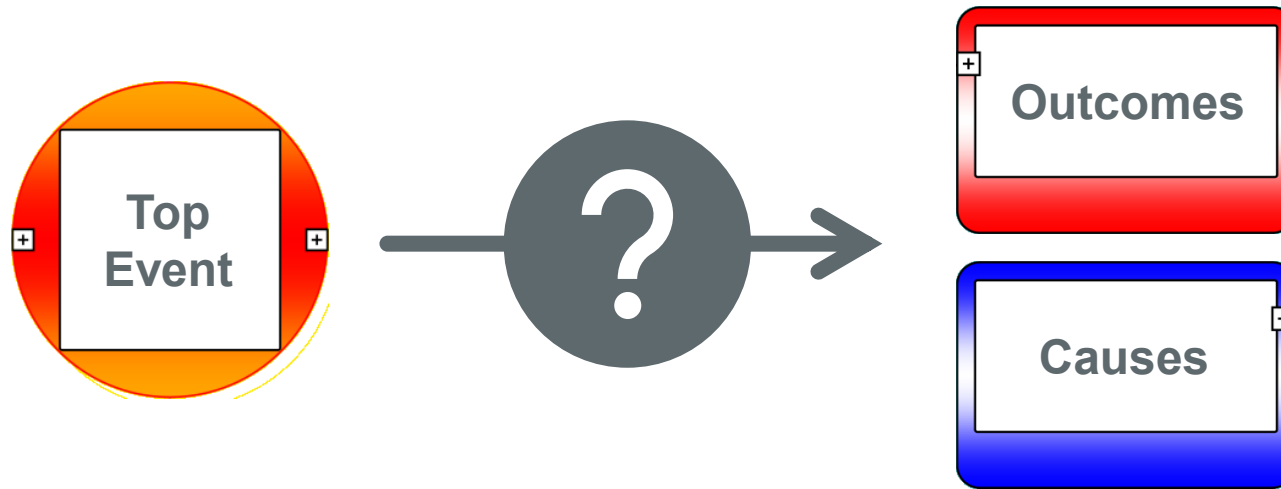
Identify the top event(s) related to the kinetic and chemical energy in a helicopter landing and departing at an offshore facility



Learning exercise (5 minutes)



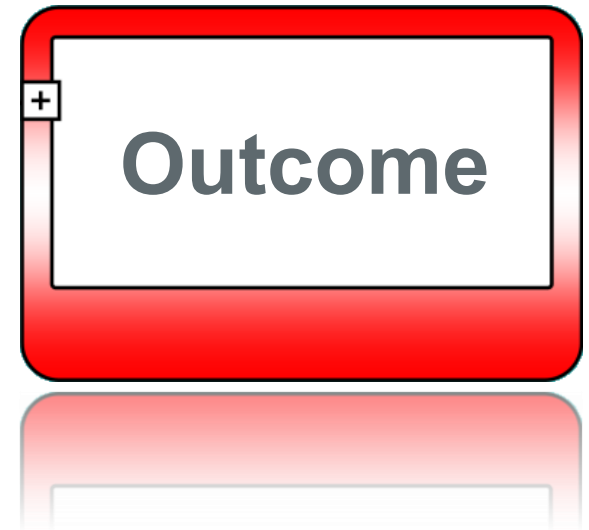
# Causes Verses Outcomes



Should you identify outcomes or causes first after top events, and does it really matter?

# Step 3 - Outcomes

*An event resulting from the release of a hazard, which results in consequences of injury, loss, or damage to targets*



# Outcome Examples



Fires and  
Explosions



Vehicle  
Collisions



Helicopter  
Crashes

In BowTie analysis, outcomes are the dangerous effects from the loss of control over hazards



# Targets

*A thing of value that is a potential recipient of the harmful effects of outcomes*



# Target Examples

- People in the immediate incident area
- People in the wider incident area
- Emergency response personnel
- Critical equipment and buildings
- Heritage and cultural sites
- Natural environment (flora and fauna)
- Production capacity
- Company share price
- Company reputation

In BowTie analysis, targets are the things of value that get damaged from the loss of control over hazards



# Consequences

*A measure of the amount of injury, loss, or damage to targets resulting from outcomes*



# Consequence Examples

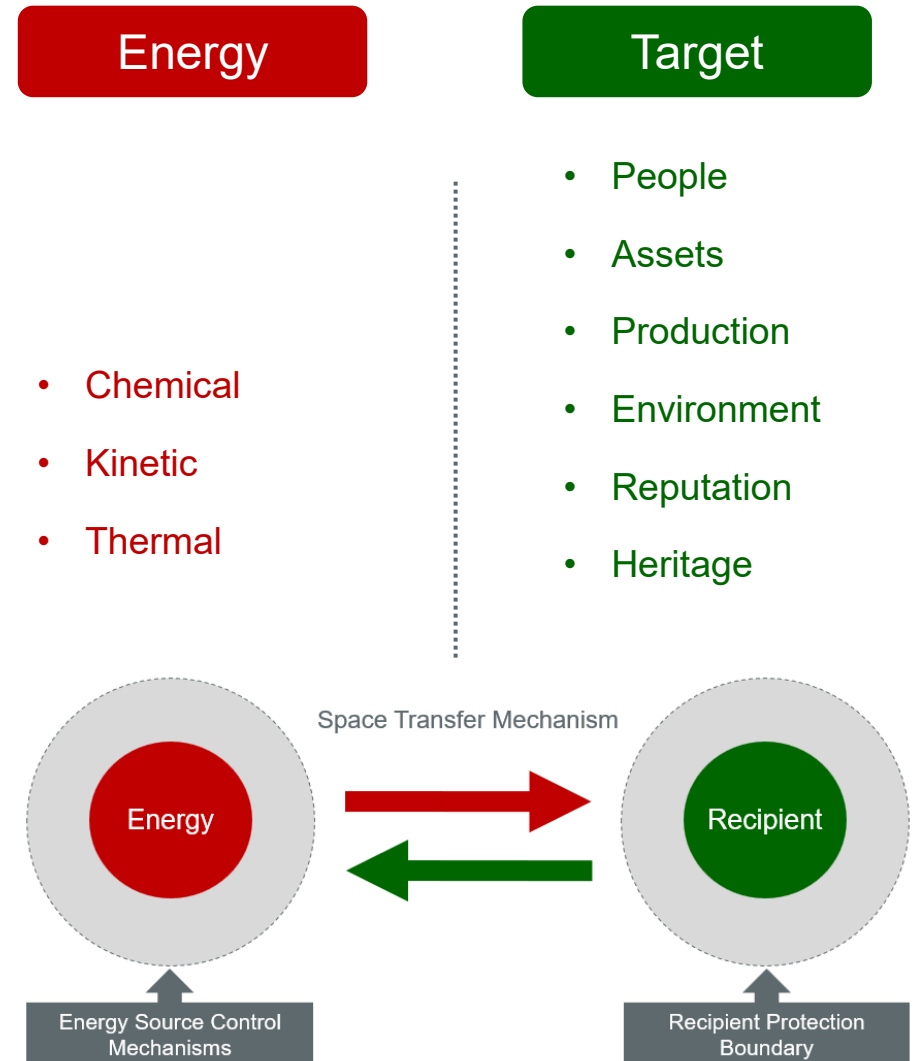
- Person(s) injured (lost time injury etc.)
- Person(s) killed
- Equipment damaged (\$)
- Production time and value lost (\$)
- Flora damaged
- Fauna injured / killed
- Reputation damaged
- Stock price reduction
- Heritage site destruction

In BowTie analysis, consequences are how we measure the damage to targets

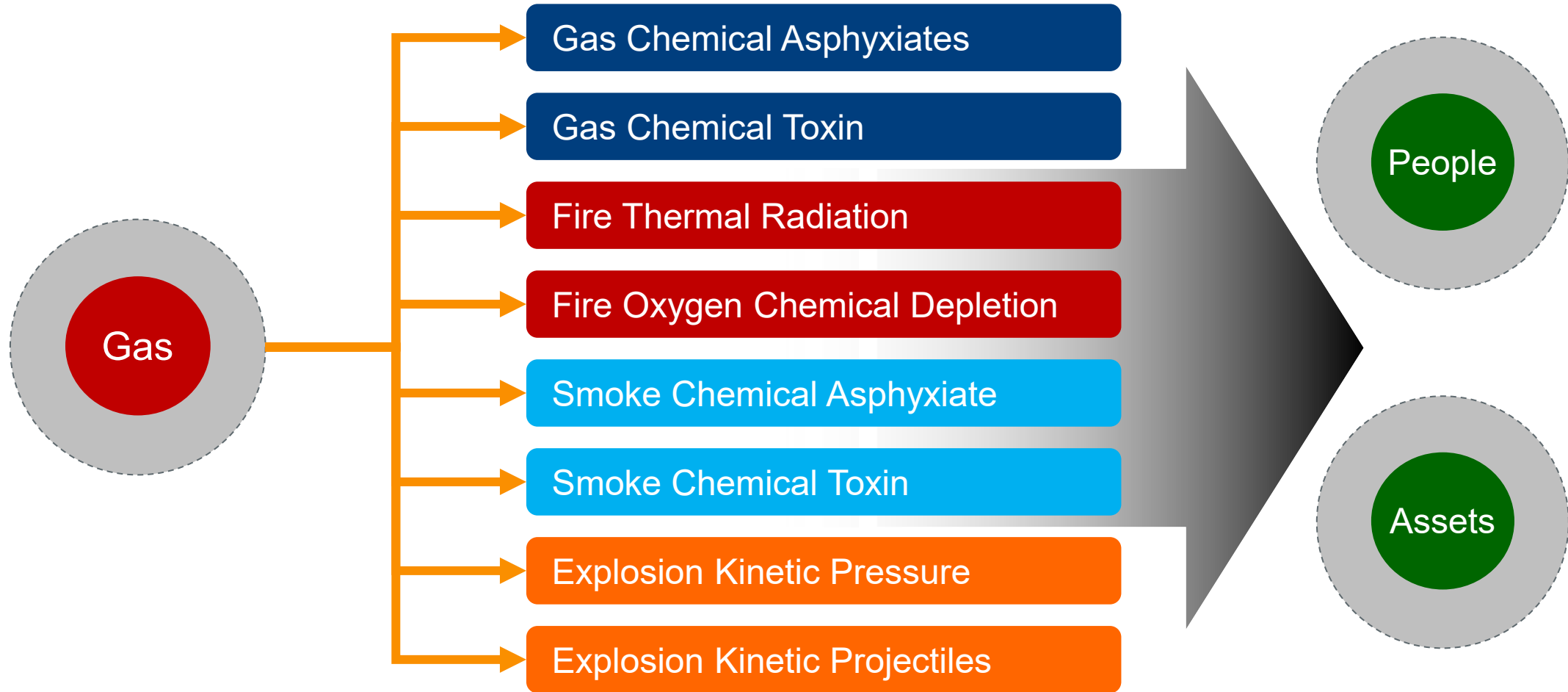


# How to Identify Outcomes

- What form(s) will the energy take or be converted into?
- What 'targets' are exposed to the different forms of energy?
- Which targets are exposed?
- Where are they located?
- How are they impacted?
- Think about transformation and escalation

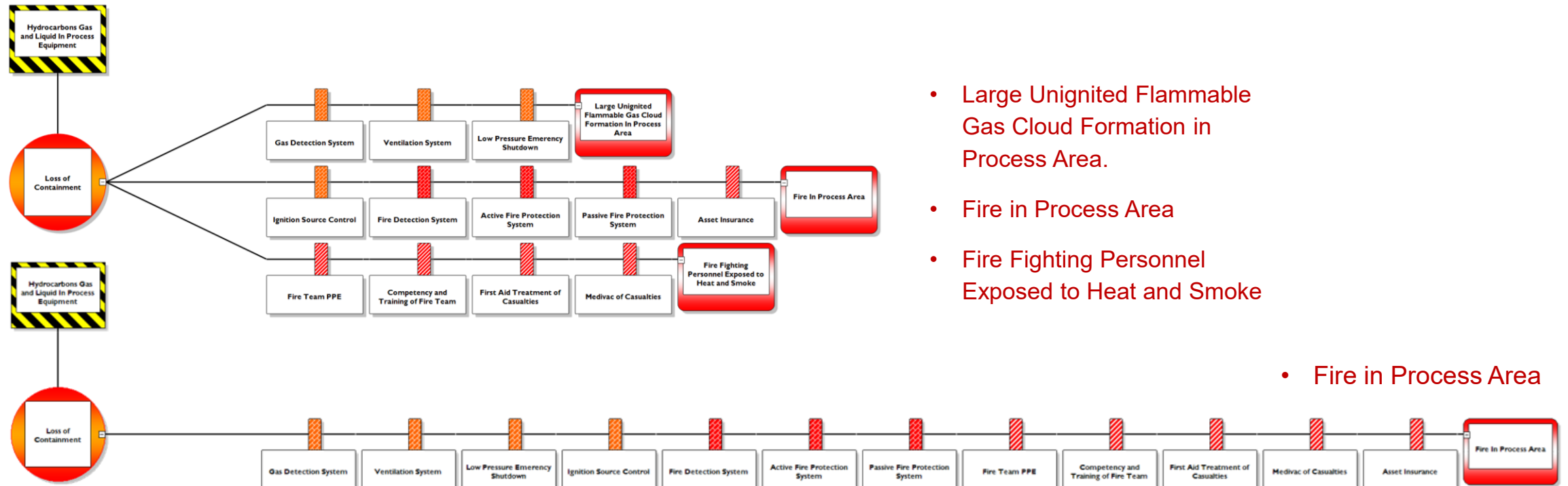


# Energy Transformation



# Specific Outcomes and Targeted Controls

The hazard, top event, and controls on these two BowTies are all the same. The only element(s) that are different are the outcomes.



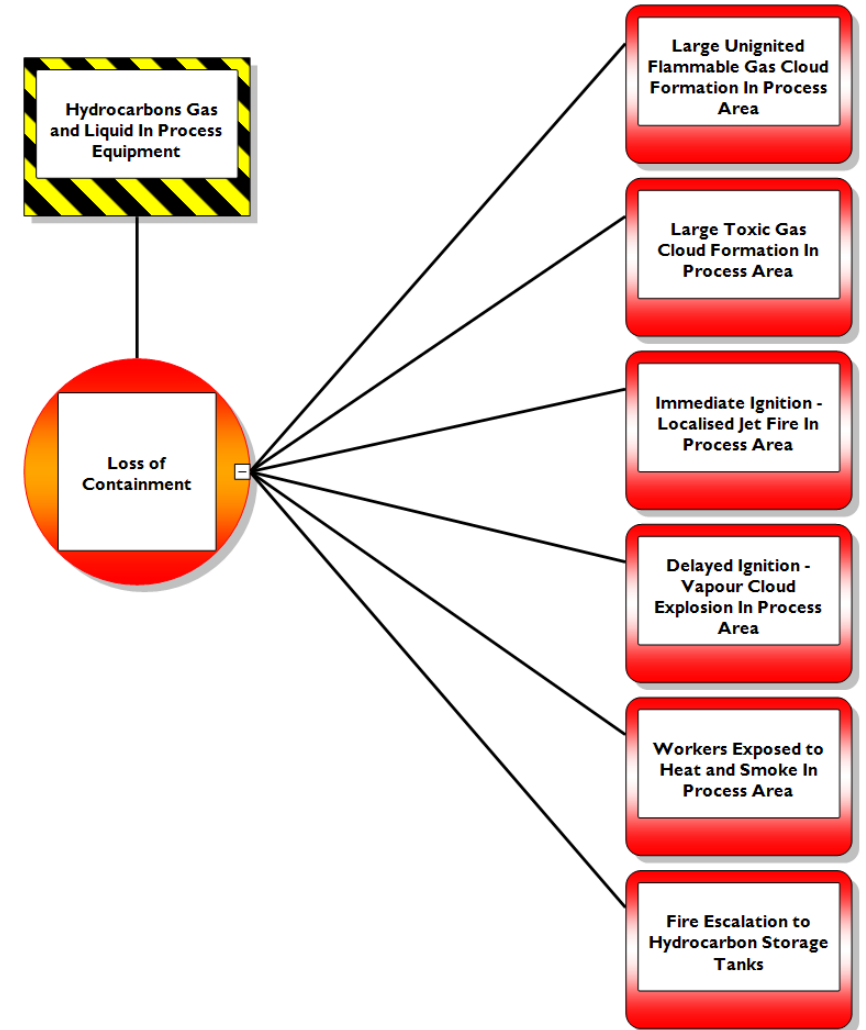
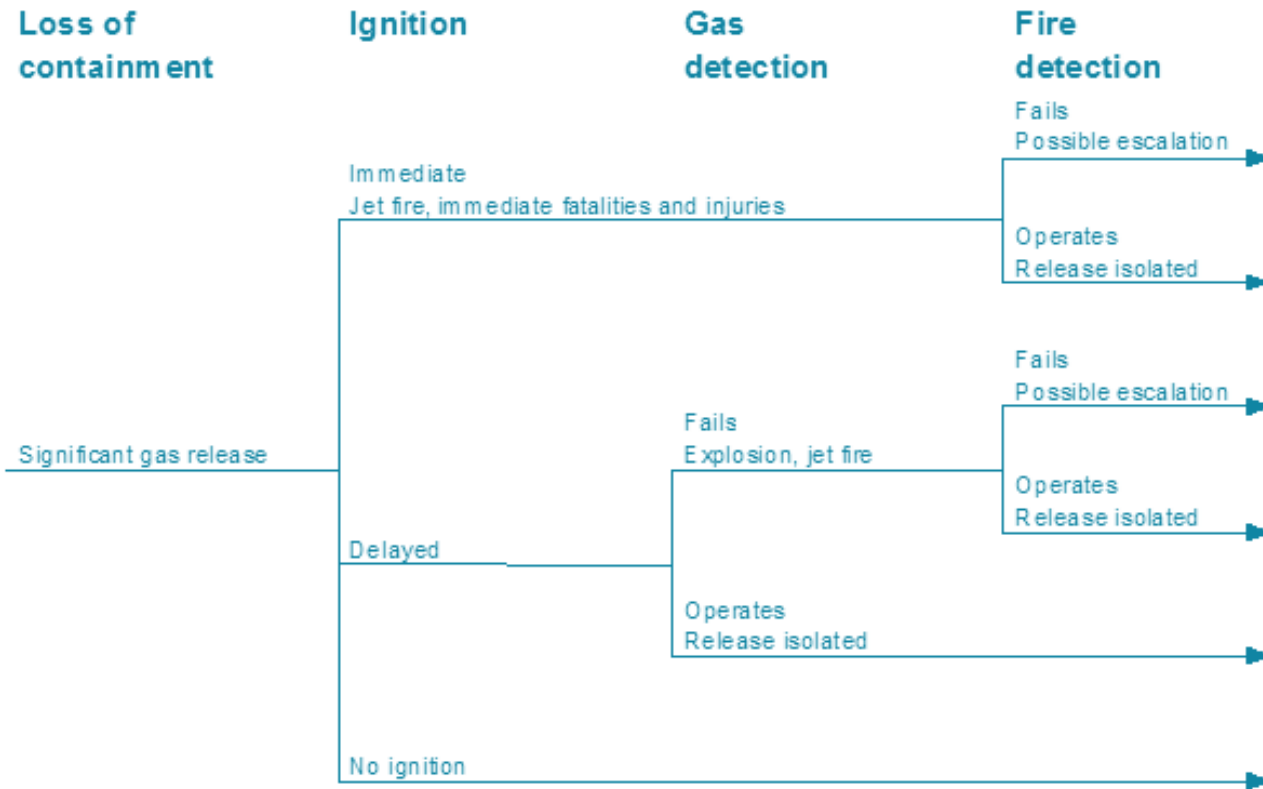
- Large Unignited Flammable Gas Cloud Formation in Process Area.

- Fire in Process Area

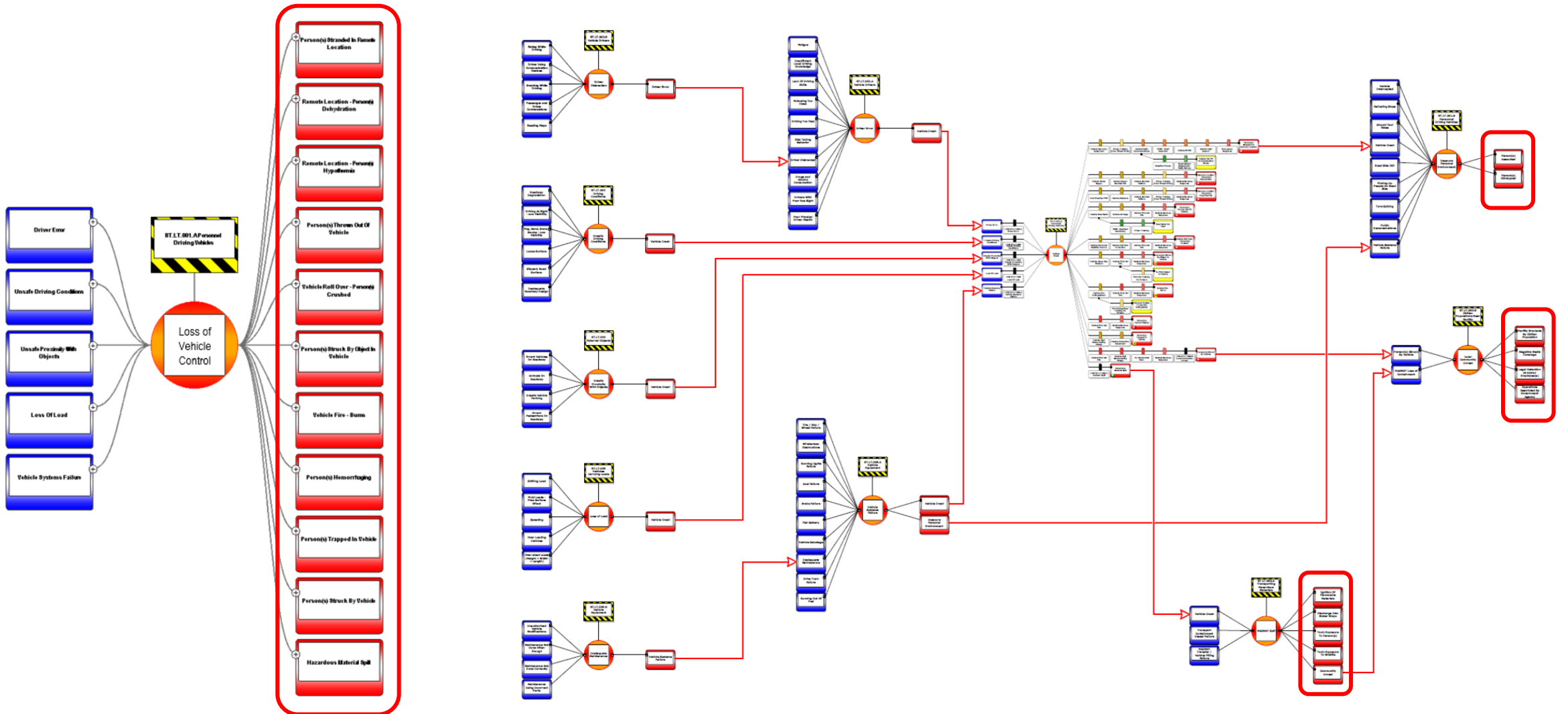
- Fire Fighting Personnel Exposed to Heat and Smoke

- Fire in Process Area

# Event Trees and Outcome Sequences



# Event Escalation and Outcome Chaining



# Where is the Risk?

*The chance of something happening that will have an impact upon objectives*

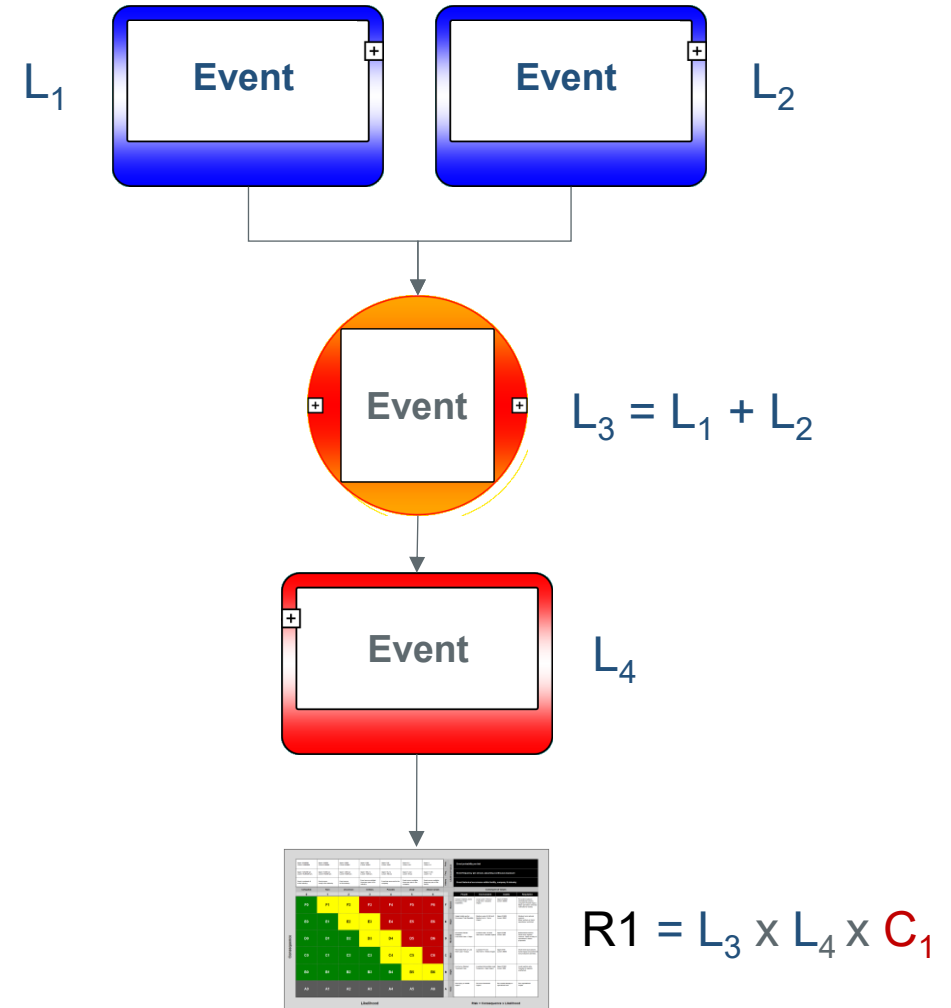
ASNZ 4360: Risk Management

*The effect of uncertainty on objectives*

ISO 31000:2009 Risk Management - Principles and guidelines

*The combination of the probability of an event and its consequence*

ISO/IEC Guide 73: Risk Management - Vocabulary



In BowTie analysis, risk is the combination of the likelihood of event(s) and their consequences

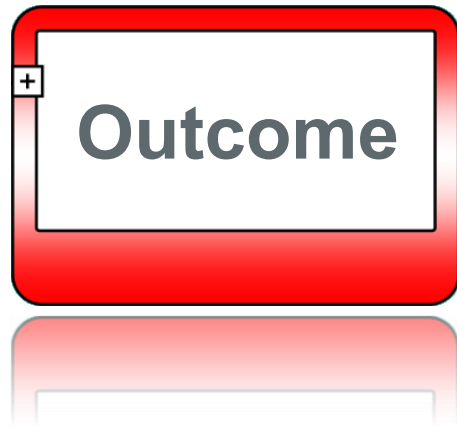


# Outcome Good Practices

- Outcomes are harmful damaging events
- Identify all outcomes for targets
- Identify all targets for outcomes
- Outcomes are not the loss or damage
- Use different outcomes for types of risk
- Consider all outcomes in the full event chain

Use these good practices when doing your BowTie analysis



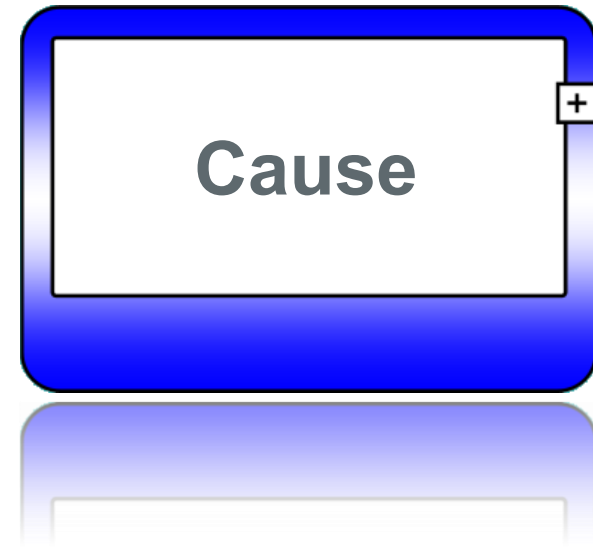


Identify the outcome(s) related to a loss of pilot control over helicopter motion and direction during landing or departure at an offshore oil and gas facility



# Step 4 - Causes

*The direct means by which the damaging properties of a hazard are released*



# Understanding Causality

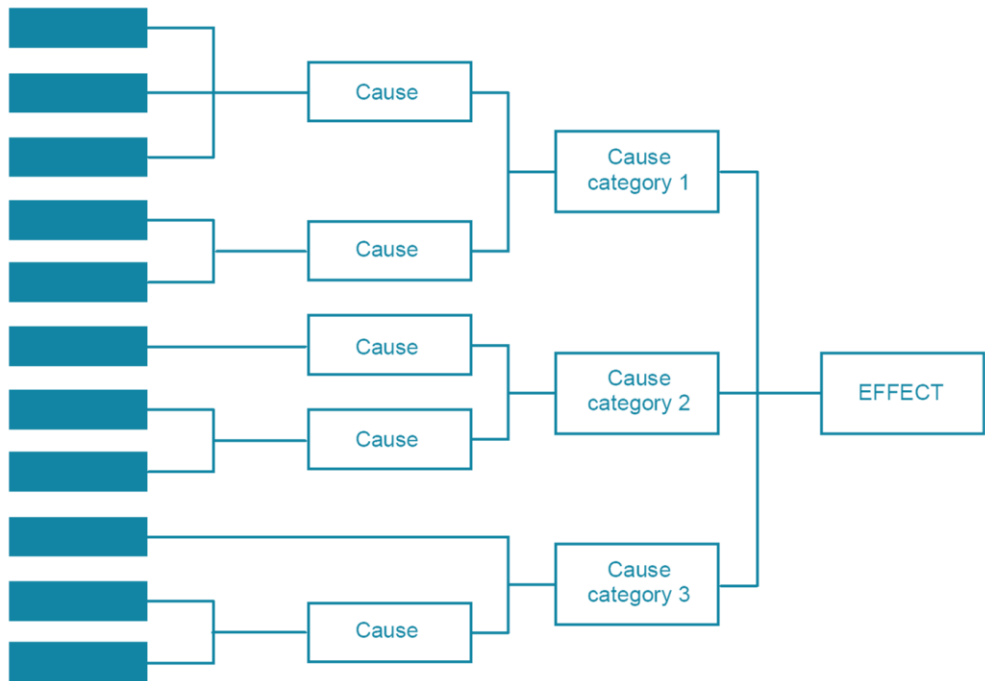
*A directional relationship in time and space between one event (cause) and another event (effect) which is the result of the first*

→ *cause* → *effect* → *cause* → *effect* →

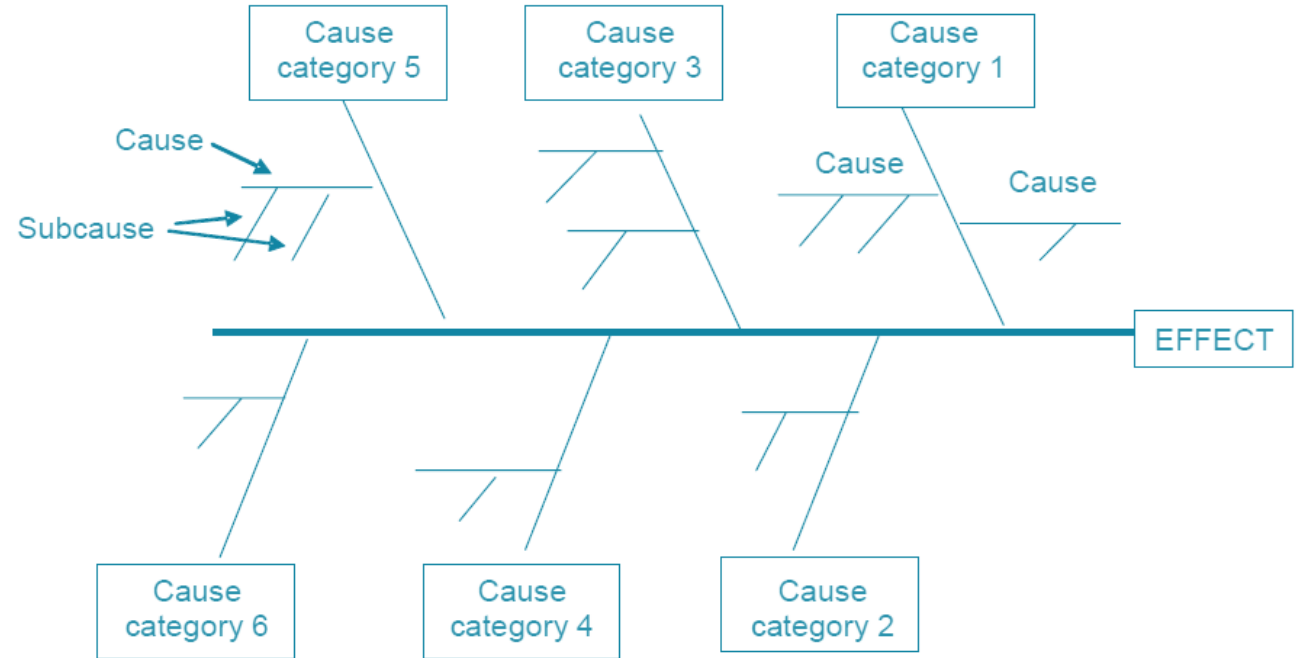
In BowTie analysis, causes are direct means by which the damaging properties of a hazard are released



# Classic Cause and Effect Analysis

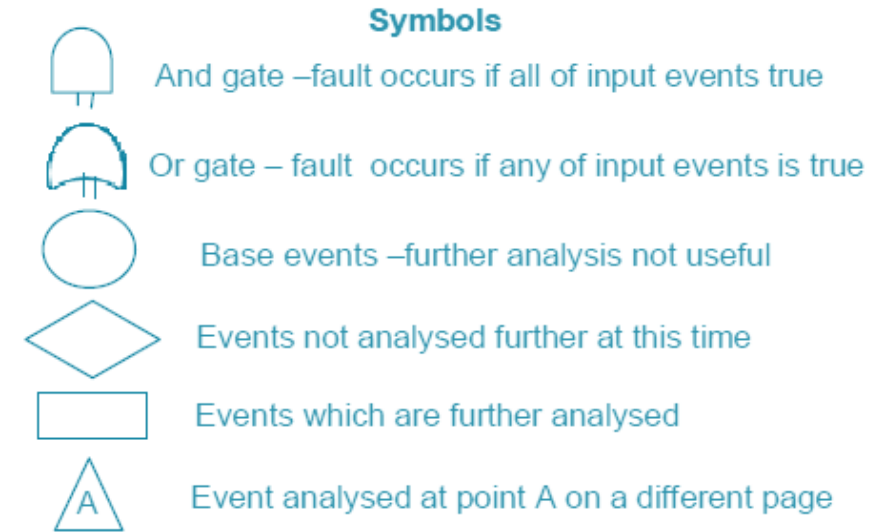
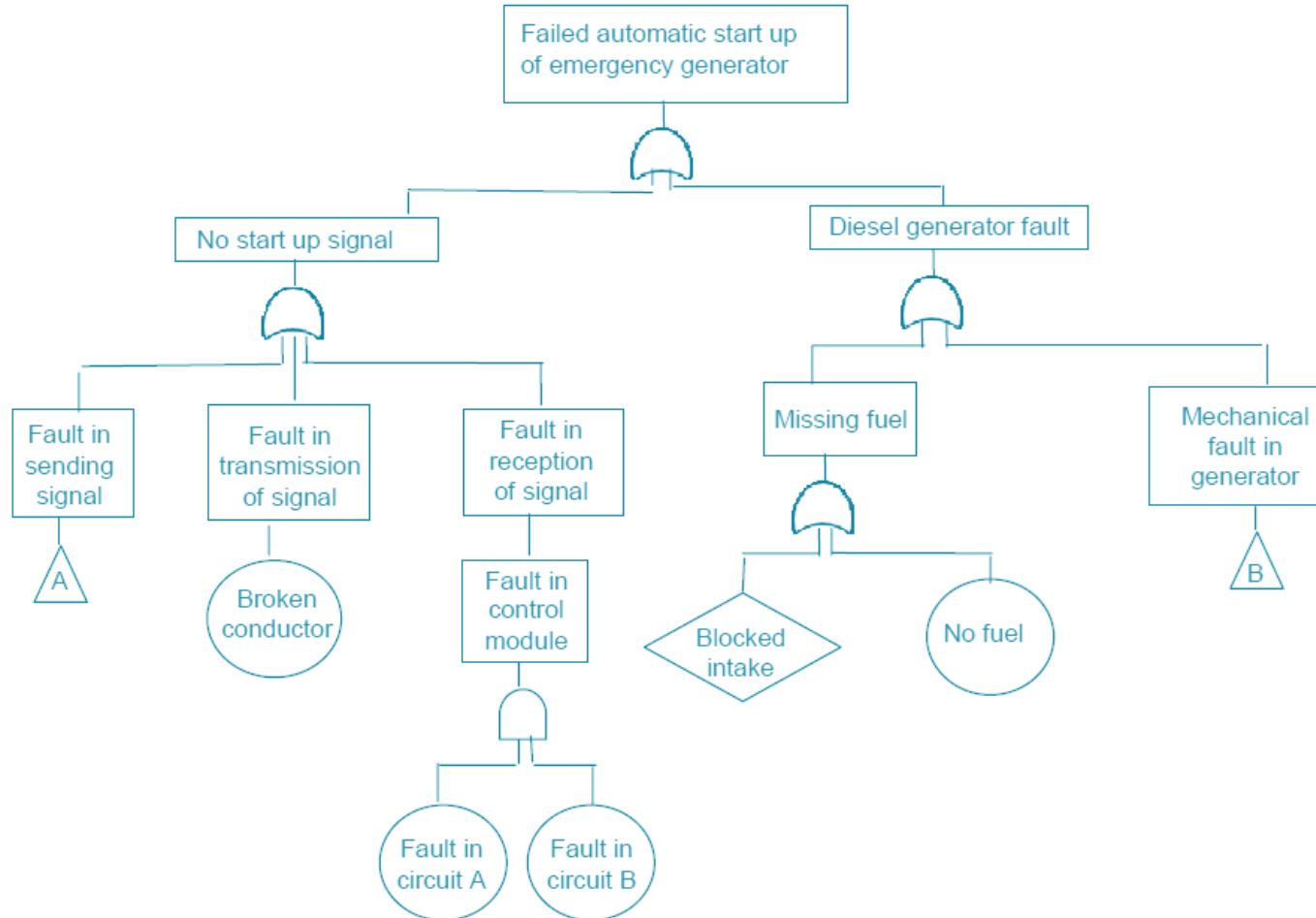


Cause and Effect Analysis



Ishikawa (Fishbone) Diagrams

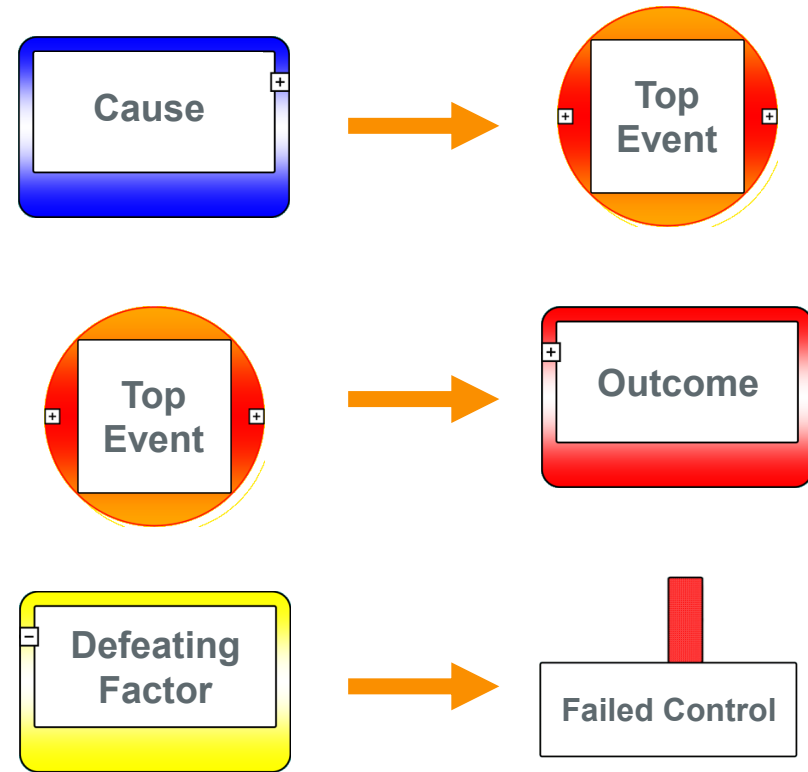
# Fault Tree Analysis



# BowTie Cause and Effect Relationships

There are only three possible cause and effect relationships in a classic BowTie analysis model

The challenge is to use these three simple relationships to reasonably represent the real-world nature of risks



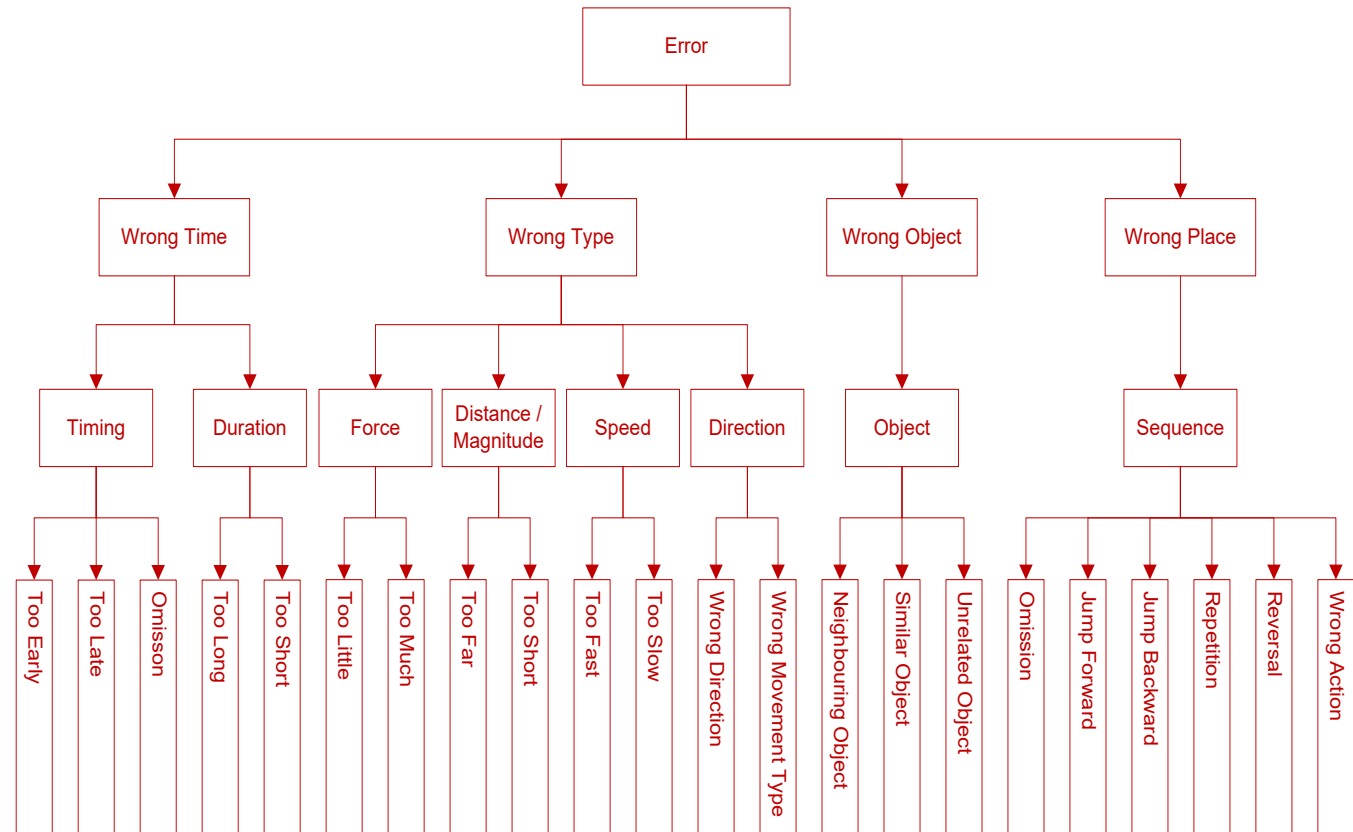
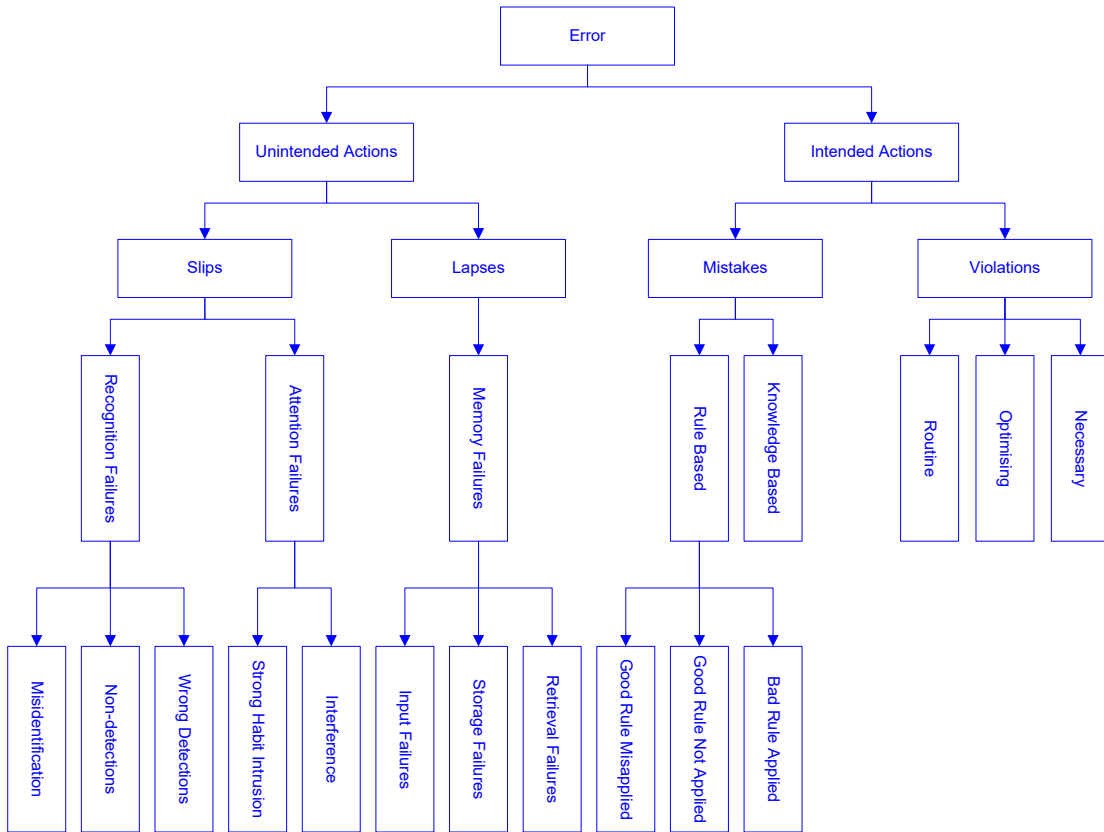
# Heinrich's First Axiom

*The occurrence of any injury invariably results from a completed series of factors, the last one being the accident itself. The accident being due to the **unsafe act of a person** and / or **mechanical or physical hazard**.*

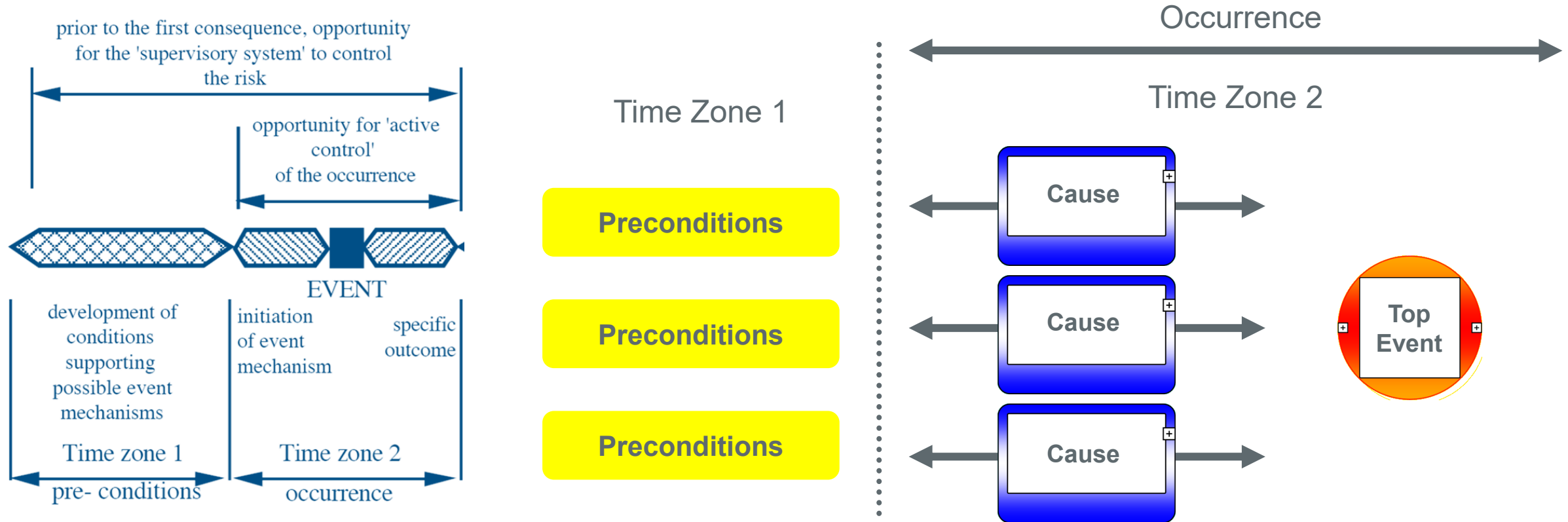
# Heinrich's Second Axiom

*The unsafe acts of persons are responsible for the majority of accidents*

# Human Error



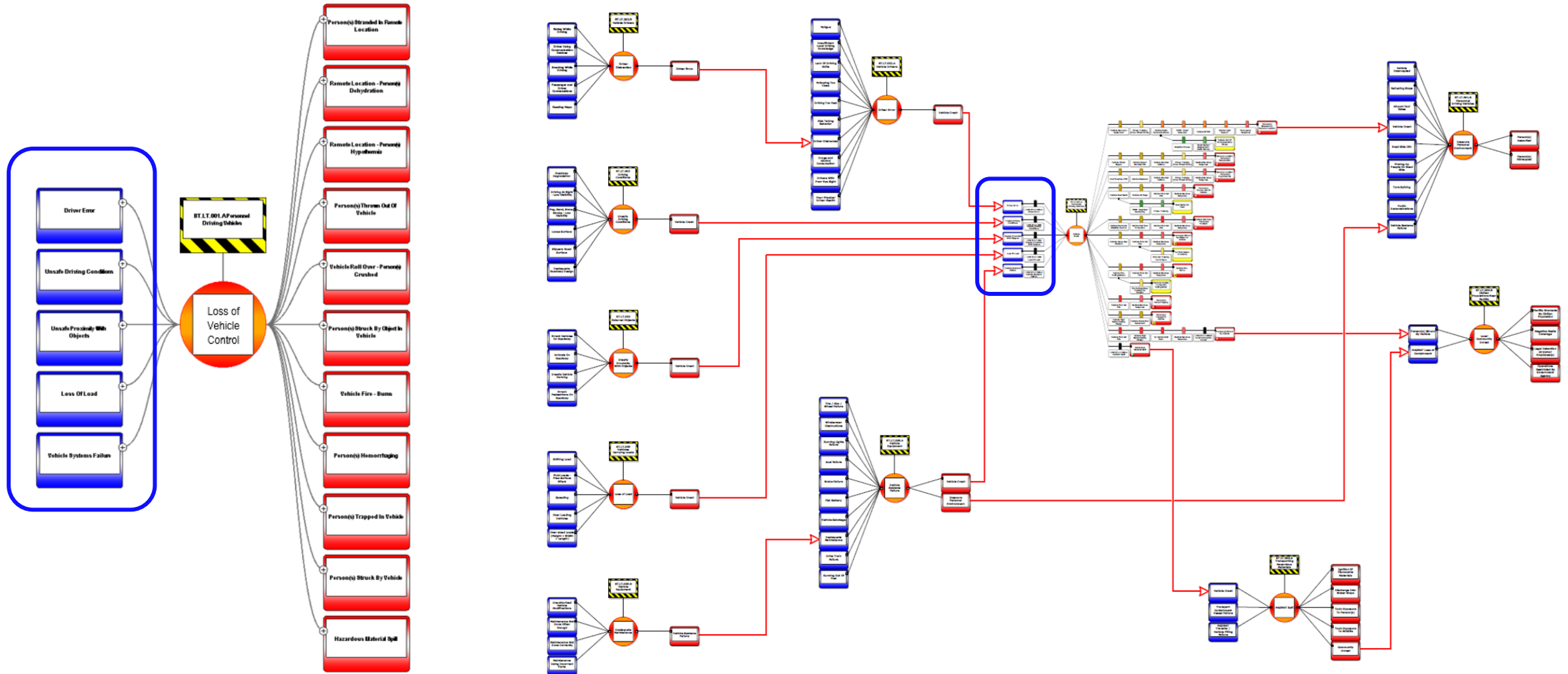
# Generalized Time Sequence Model



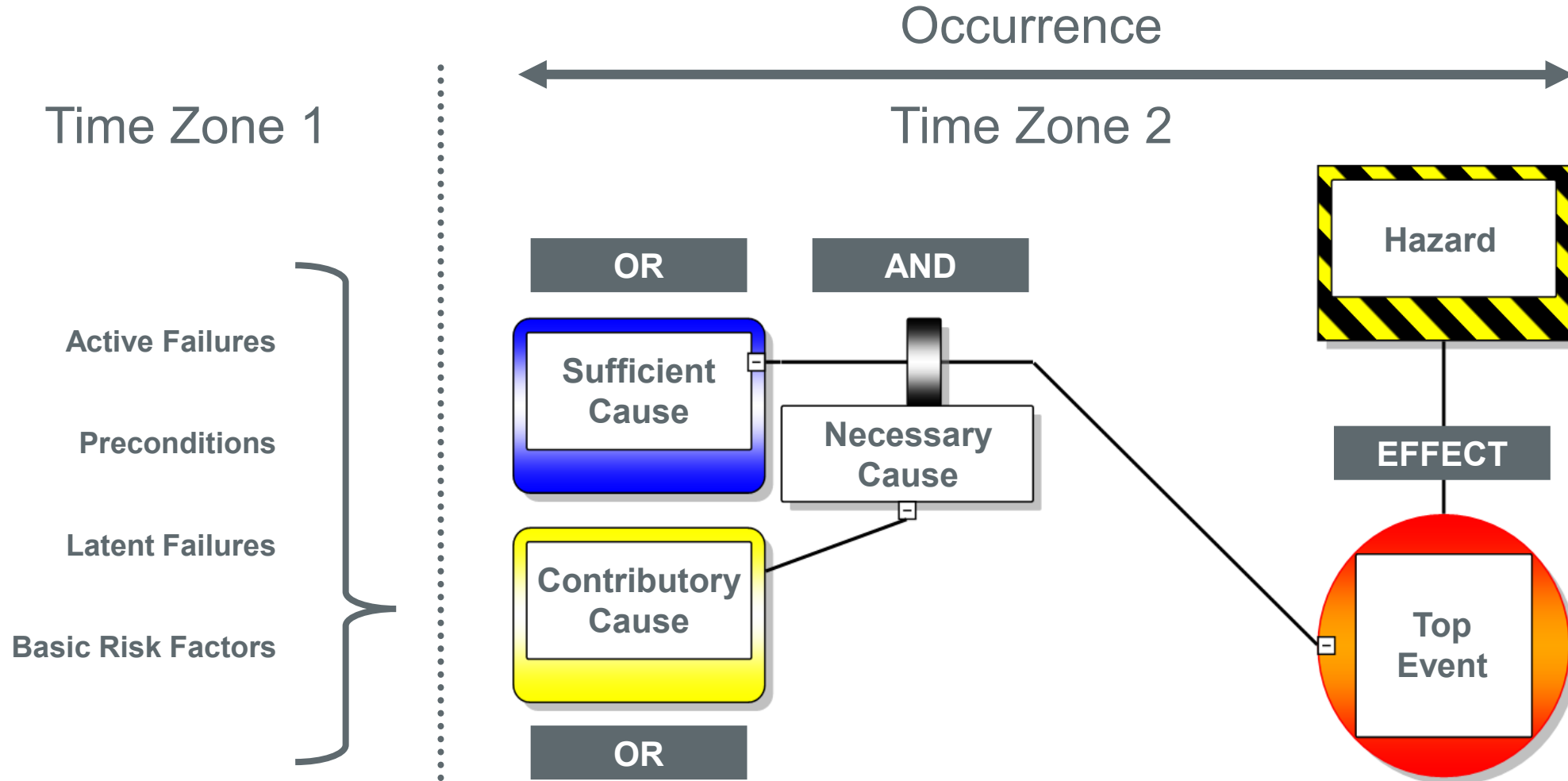
In BowTie analysis, causes are direct means by which the damaging properties of a hazard are released



# Causality Categories and Chaining



# Logical BowTie Causality Model



# Cause Examples



Equipment  
Corrosion



Driver  
Distraction



External  
Interference

In BowTie analysis, causes are direct means by which the damaging properties of a hazard are released

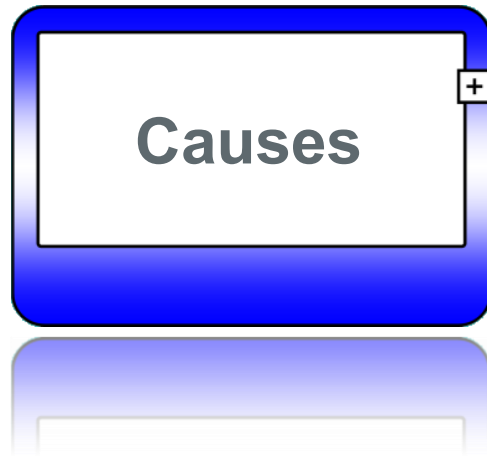


# Cause Good Practices

- Group causes into categories for more targeted analysis
- Causes need to be 'sufficient' in and of themselves
- Causes should be independent of each other
- Control failures are not causes
- Consider the prevalence of the cause
- Each cause should lead to every outcome
- Causes should have low temporal ambiguity (time and space)

Use these good practices when doing your BowTie analysis





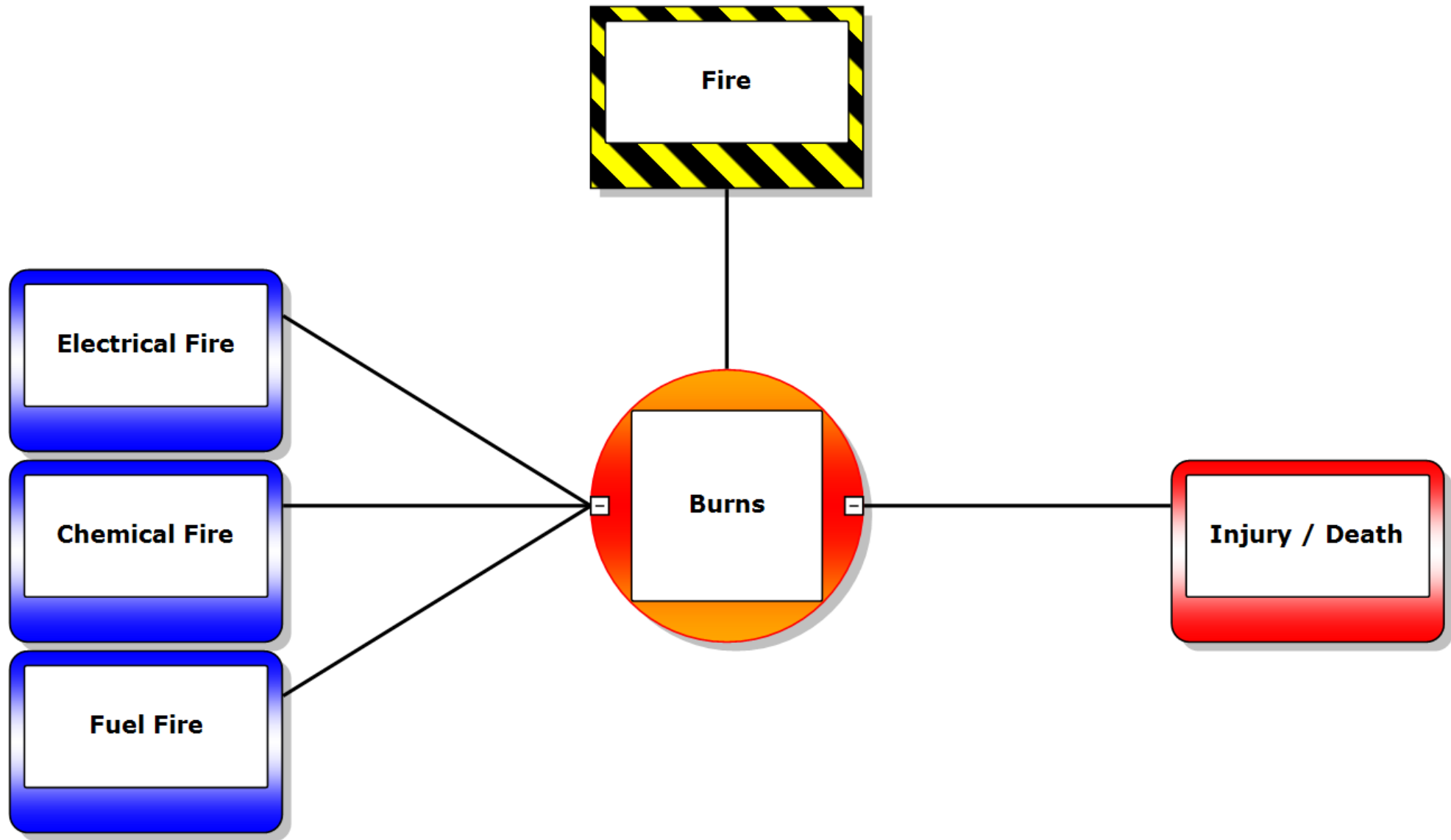
Identify the causes of a loss of pilot control over helicopter motion and direction during landing or departure at an offshore oil and gas facility



# Modelling Phase Summary

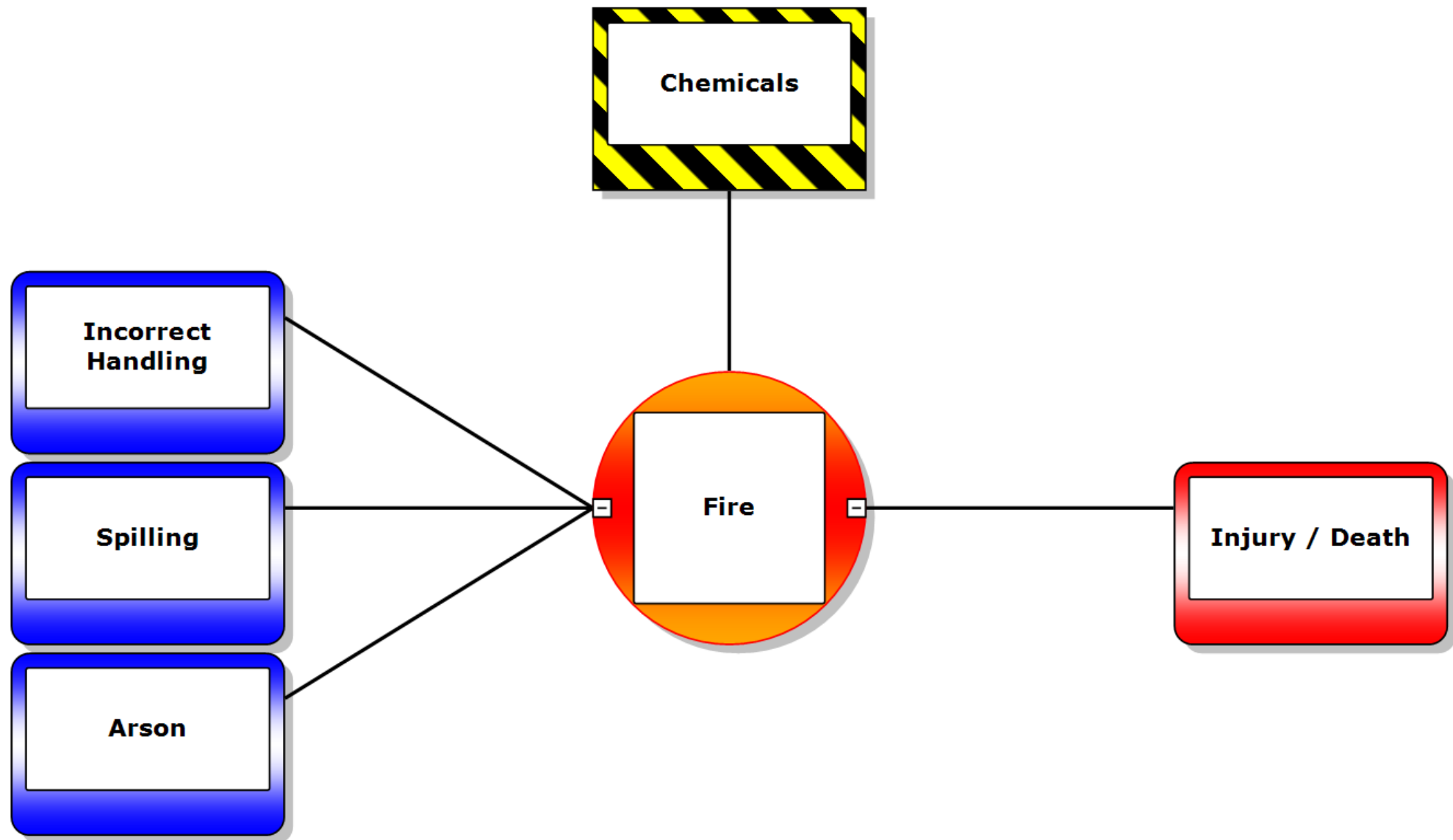
What have we learned so far ...





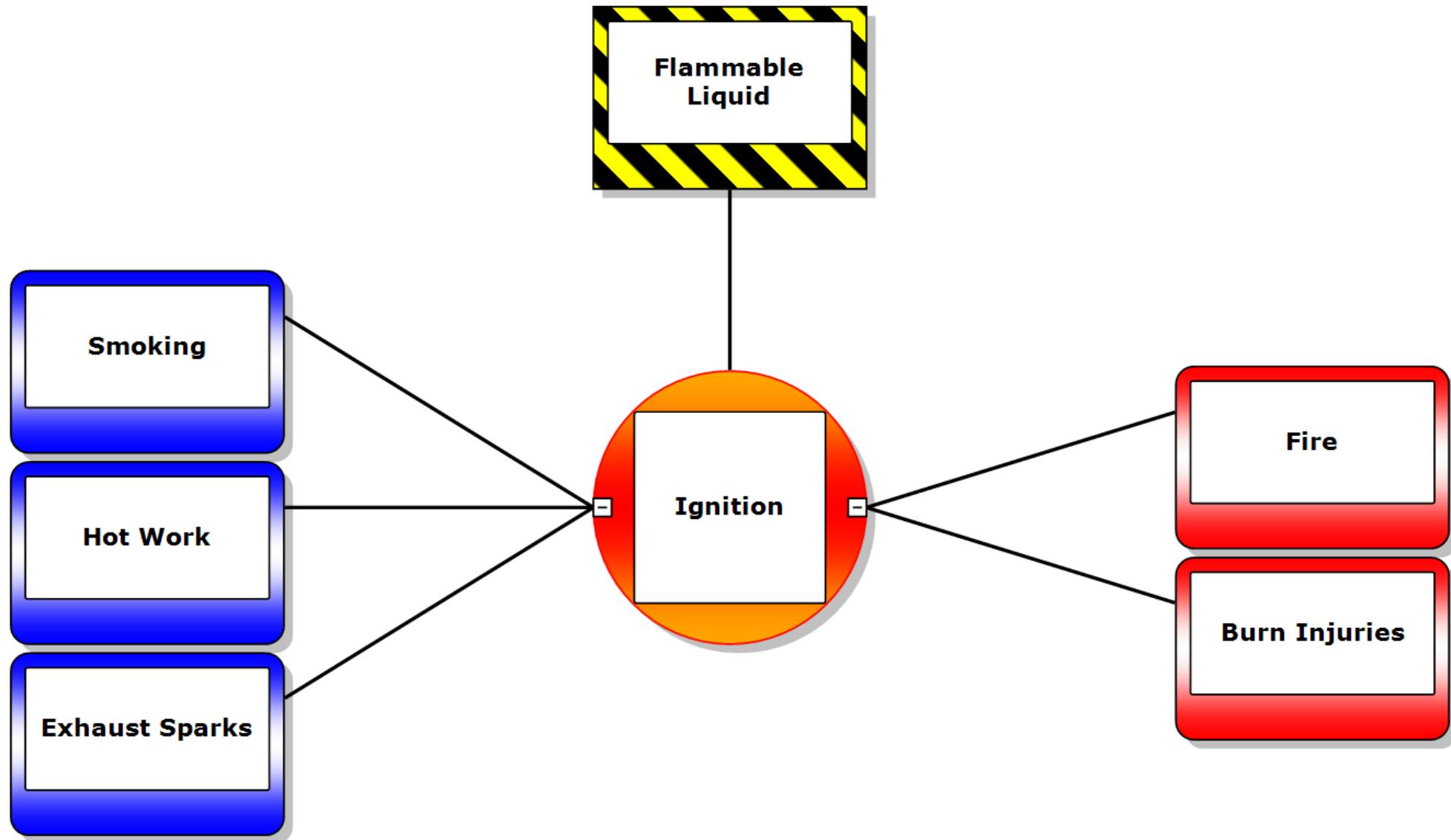
What do you think is 'wrong' with this bowtie model?





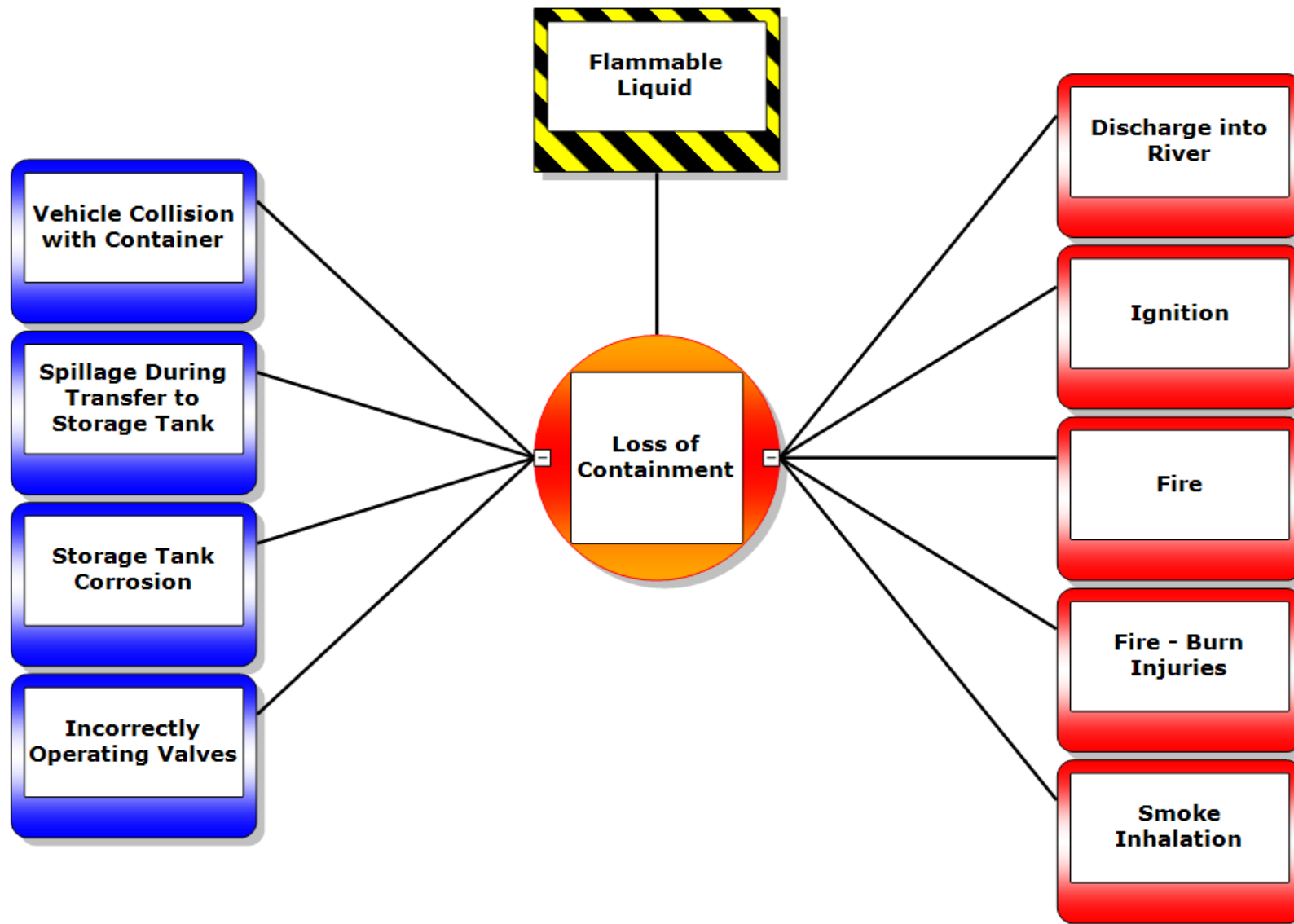
What do you think is 'wrong' with this bowtie model?





What do you think is 'wrong' with this bowtie model?





What do you think is 'wrong' with this bowtie model?



# Modelling Good Practices

- Think across the entire accident scenario and not just in time zone 2
- Keep model events in the correct time zone
- Use cause and outcome event categorization, escalation, and chaining
- Avoid ambiguity and be efficiently descriptive
- Apply an iterative discovery process
- Your first model is never 'correct'
- Never develop initial models in a workshop with non-risk experts
- Update the model during the control phase
- Park controls identified during modelling for later analysis

Use these good practices when doing your BowTie analysis





Create a BowTie model for the kinetic energy in a moving land transport vehicle, that is used to transport mining personnel to a remote location



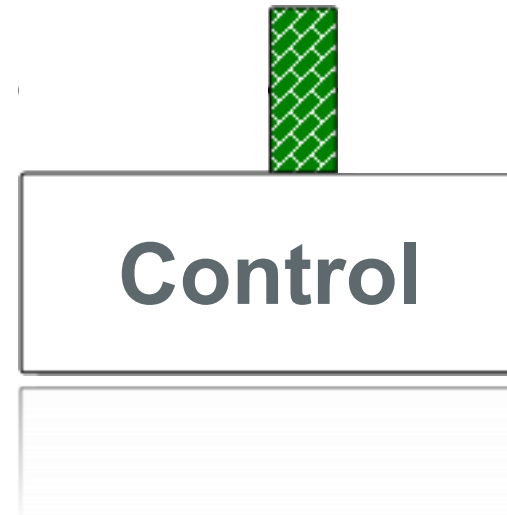
# Control Phase

Disrupting the process of injury, loss and damage

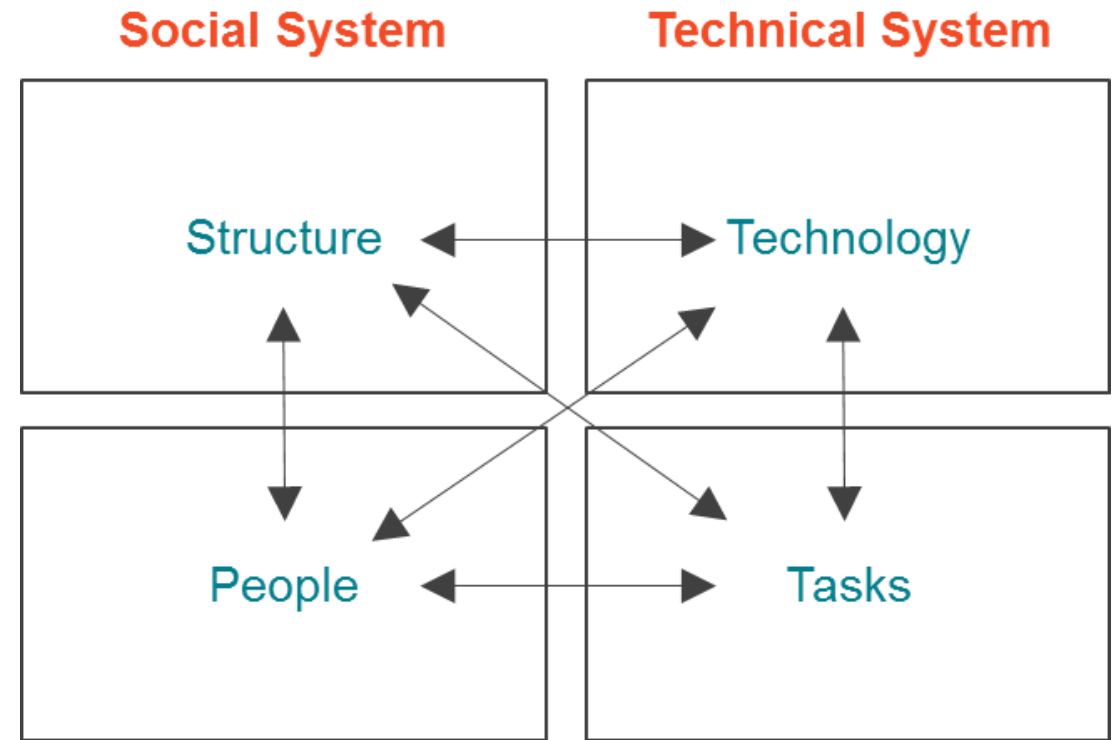
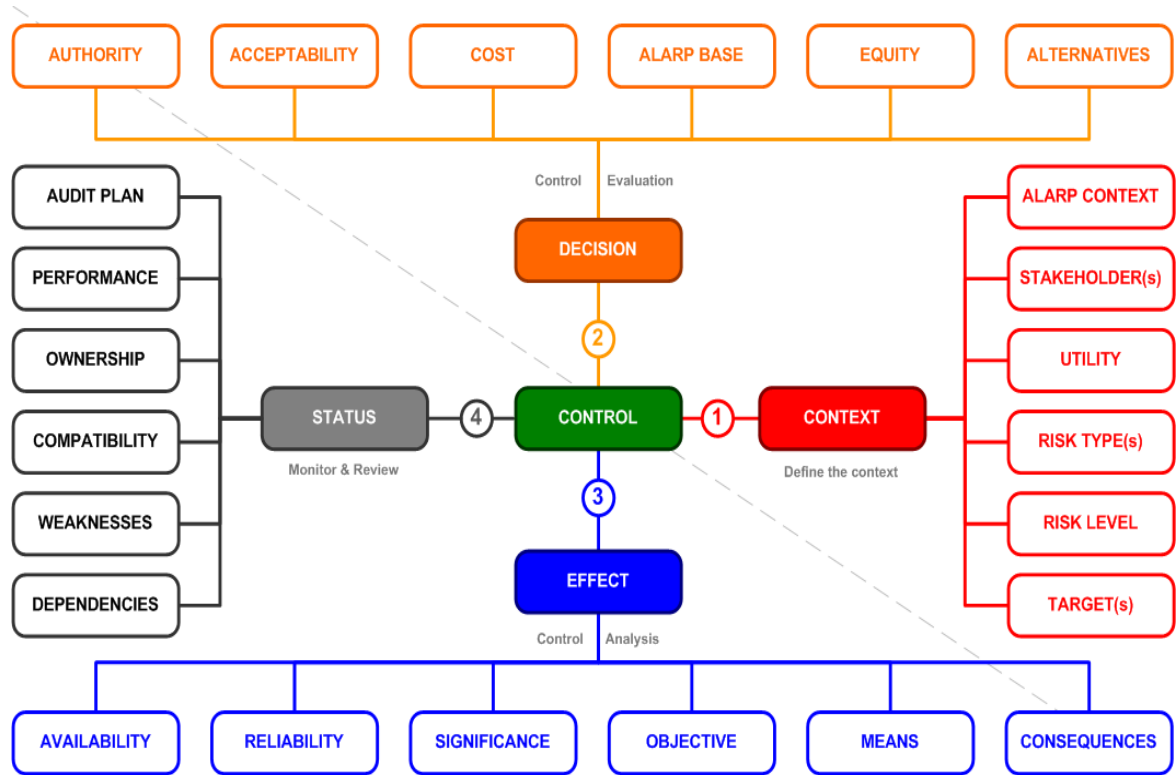


# Phase 2 - Controls

*An intentional measure taken to modify risk by disrupting the process that leads to injury, loss, or damage*



# Controls are Very Complicated



# Conditions and Circumstances

*Conditions are defined as those features of the environment that change sufficiently slowly for the fact of change to be non-recognisable.*

- Location of equipment
- Pressure in vessels
- Toxicity of substances

*Circumstances are defined as those aspects of the working environment that are subject to fairly regular and recognisable change.*

- Wind speed
- Wave height
- Day / night
- Water depth
- Weight of lifted objects

**Conditions and circumstances are not controls**

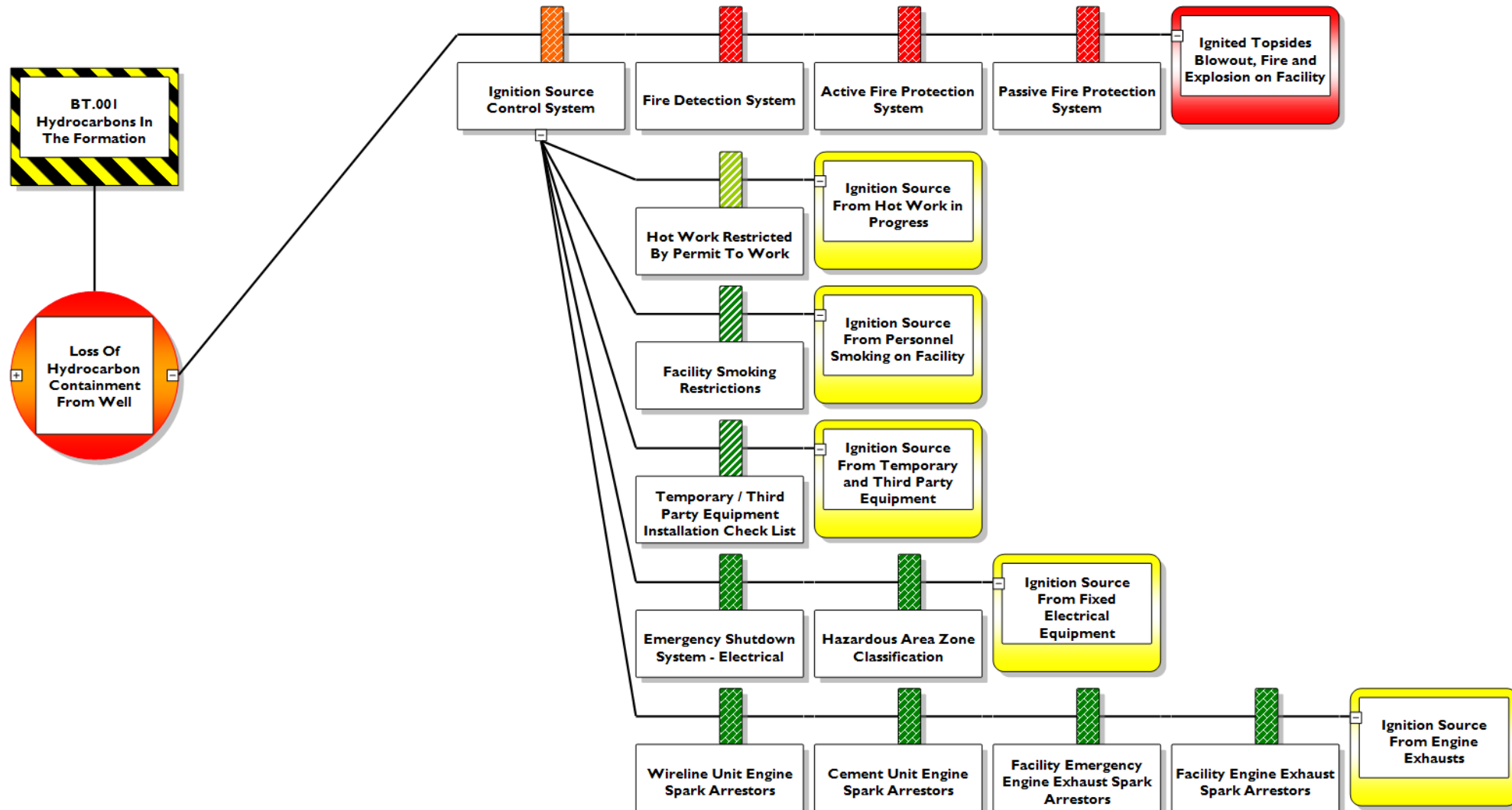
# Control Declaration

The declaration (i.e. name) of the controls should be brief and unambiguous. Focus on 'what it is' and do not include:

- How it works
- When it is used
- What it does
- Who uses it
- Exceptions and disclaimers



# System Based Control Declaration



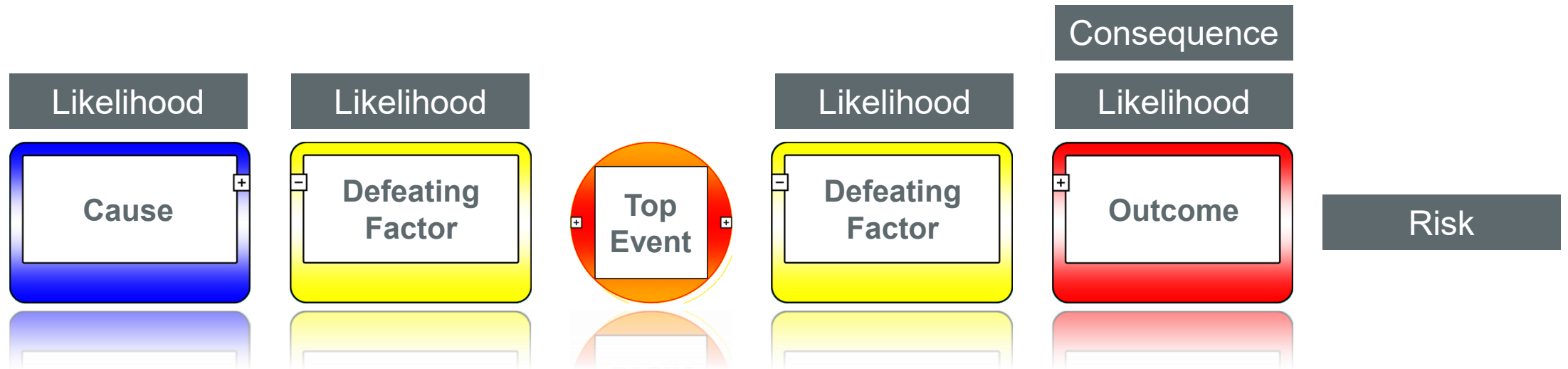
# Control Type

What type of effect do controls provide



# Controls are Defined by their Context

What is being modified by the control?



In BowTie analysis, controls are an intentional measure taken to modify risk



# Why do we Categorize Controls

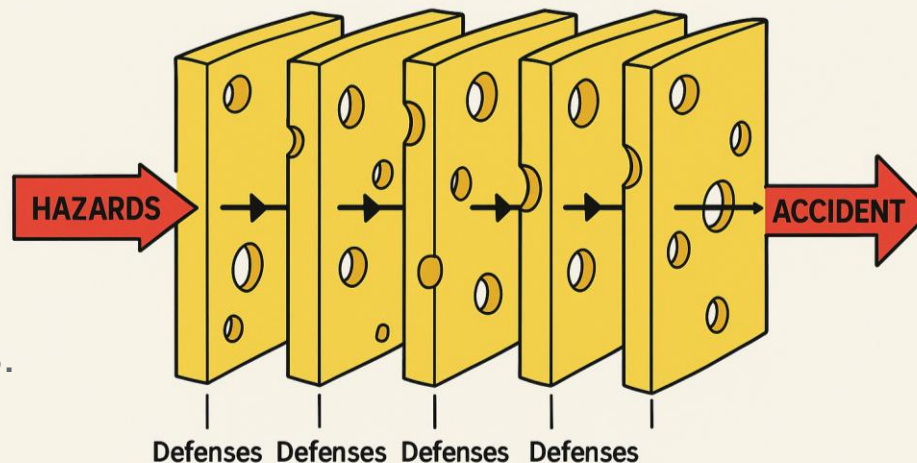
Defense in Depth



Complexity of Control

We want to build a highly resilient control pathway

**Defence in depth** is a strategy that is intended to ensure that there are multiple layers of controls which can disrupt the process of injury, damage or loss.



**Complexity of control** is a strategy that is intended to ensure that common underlying causal factors do not defeat all controls which are placed in the control pathway.

# Standard OHS Hierarchy of Controls



1 Elimination

2 Substitution

These control types should be in place before even considering BowTie analysis



3 Isolation

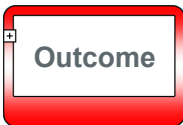


4 Engineering controls

These control types, whilst relevant, are not sufficient for a detailed event-based risk analysis model

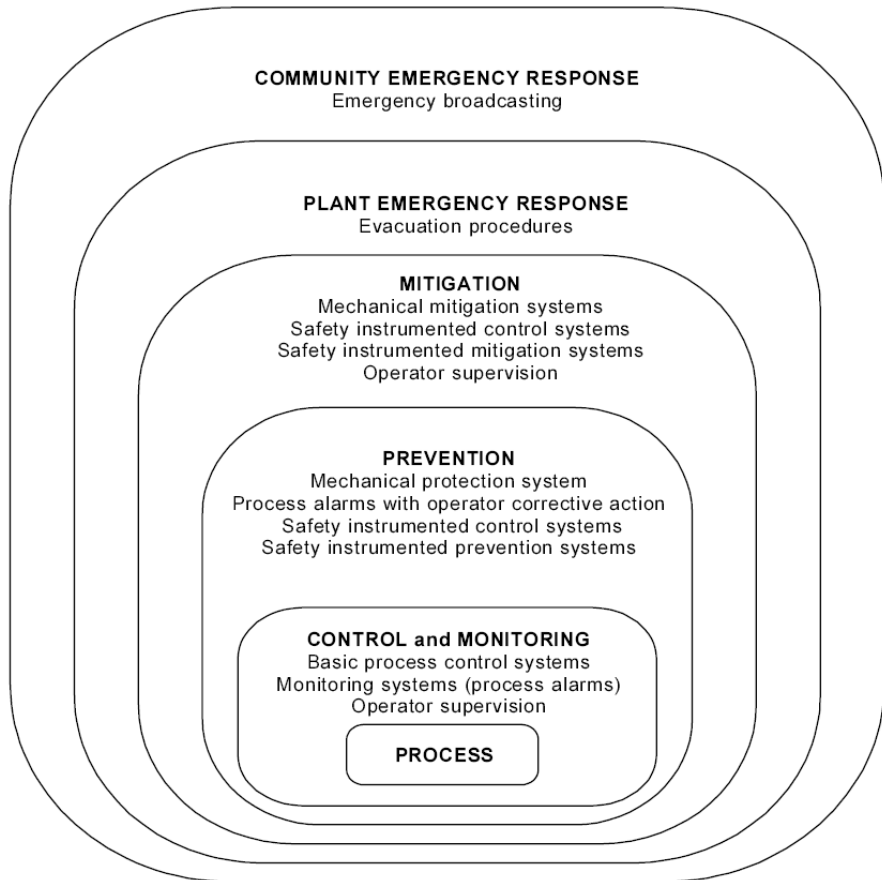


5 Safe work practices



6 PPE

# Layers of Protection Analysis



LOPA may be used qualitatively simply to review the layers of protection between a hazard or causal event and an outcome. Normally a semi-quantitative approach would be applied to add more rigour to screening processes for example following HAZOP or PHA.

LOPA provides a basis for the specification of independent protection layers (IPLs) and safety integrity levels (SIL levels) for instrumented systems, as described in the IEC 61508 series and in IEC 61511, in the determination of safety integrity level (SIL) requirements for safety instrumented systems.

LOPA can be used to help allocate risk reduction resources effectively by analysing the risk reduction produced by each layer of protection.

# Hollnagel's Barrier Classes

## Physical

Physically prevents an action or event occurring. these provide a physical opposition to the transfer of energy. e.g. walls, buildings, fences, guards, containers.

## Functional

Impedes or interrupts an action or event by requiring pre-conditions to be met or specific actions taken before the action of event will be permitted to occur. e.g. interlocks, passwords, equipment controls.

## Symbolic

Requires an act of interpretation and compliance by an intelligent agent in order to achieve their objective. e.g. visual alarms, audible alarms, signage, boundary lines.

## Incorporeal

Lacks material form or substance and relies on the knowledge and compliance of the operator to achieve their objective. e.g. rules, policies, restrictions, laws.

# Haddon's 10 Countermeasures

## Pre Accident

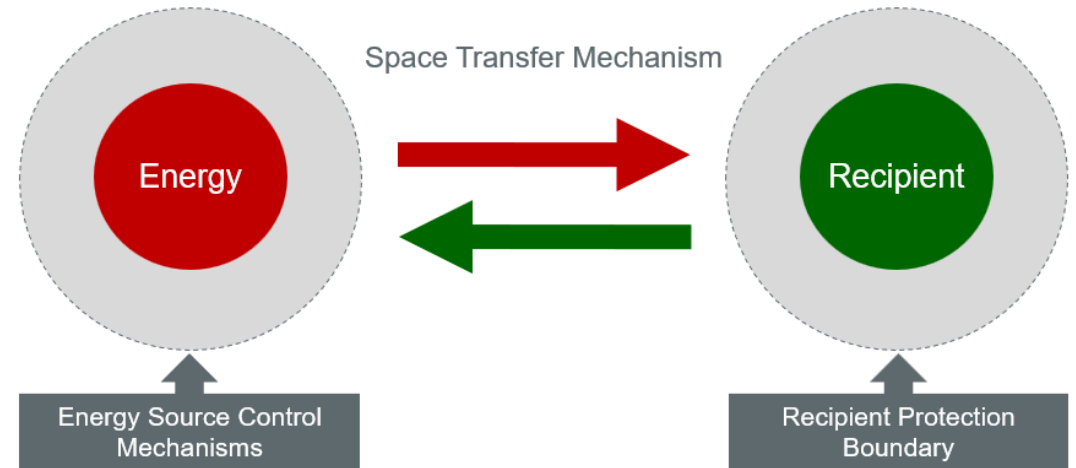
1. Prevent hazard build-up
2. Reduce hazard build-up
3. Prevent hazard release

## Accident

4. Modify hazard release
5. Separate in time and space
6. Interpose a 'barrier'
7. Modify target surface
8. Strengthen target structure

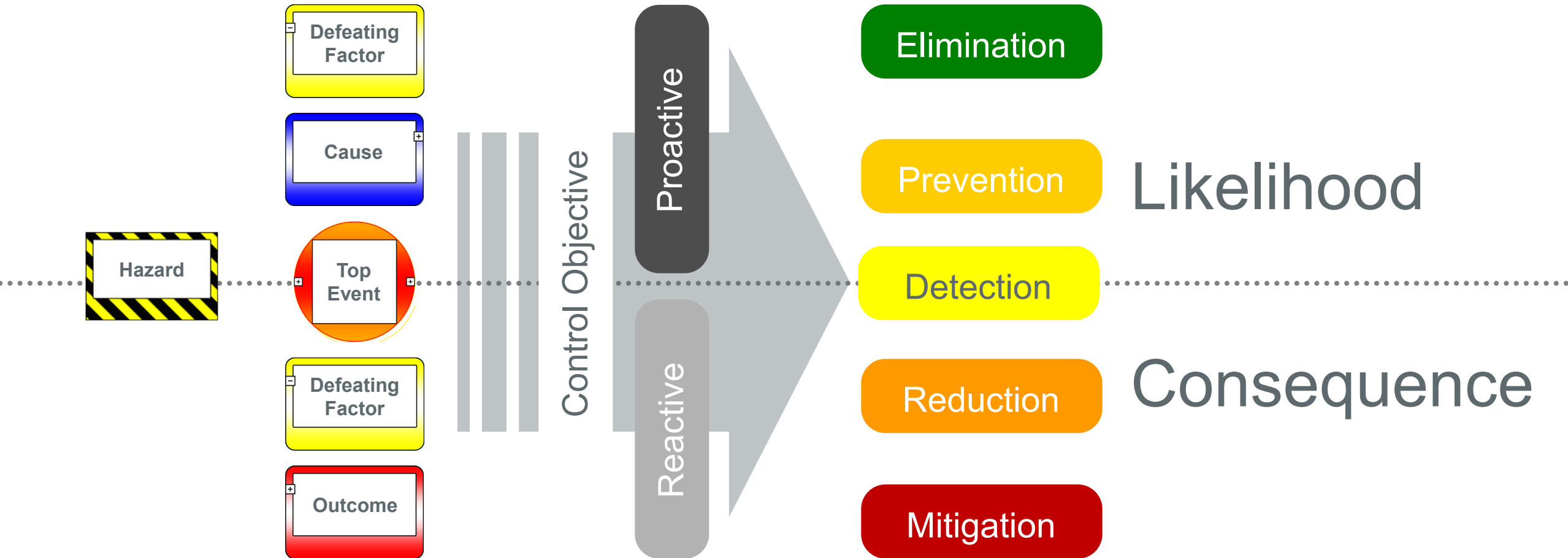
## Post Accident

9. Rapid detection of damage
10. Ameliorate the damage



# Defense in Depth

*Control 'objective'*



# Control Objective

Elimination

*Removing or avoiding something*

Designing out the problem should always be the first objective. These types of controls often do not appear in risk plans simply because the risks are known not to exist because of the existing elimination controls.

Elimination controls are primarily related to causes and defeating factors.

# Control Objective

Prevention

*Obstructing or stopping something*

Where things cannot be eliminated, additional measures should be taken to prevent them from leading to top events and outcomes.

The objective of prevention controls is primarily related to causes and defeating factors.

# Control Objective

Detection

## *Identifying something*

In order to implement other control measures, it can often be important to be aware that things are about to go wrong or have gone wrong.

The objective of detection controls is primarily related to top events and outcomes but can also be used to manage causes and the failure of other controls.

# Control Objective

Reduction

*Decreasing, lessening or limiting something*

There is always potential for prevention controls to fail and so reduction measures should be considered to limit the scale and severity of any top event or outcome which may arise.

The objective of reduction controls is primarily related to outcomes, but may also play a role in causes and defeating factors in certain situations.

# Control Objective

Mitigation

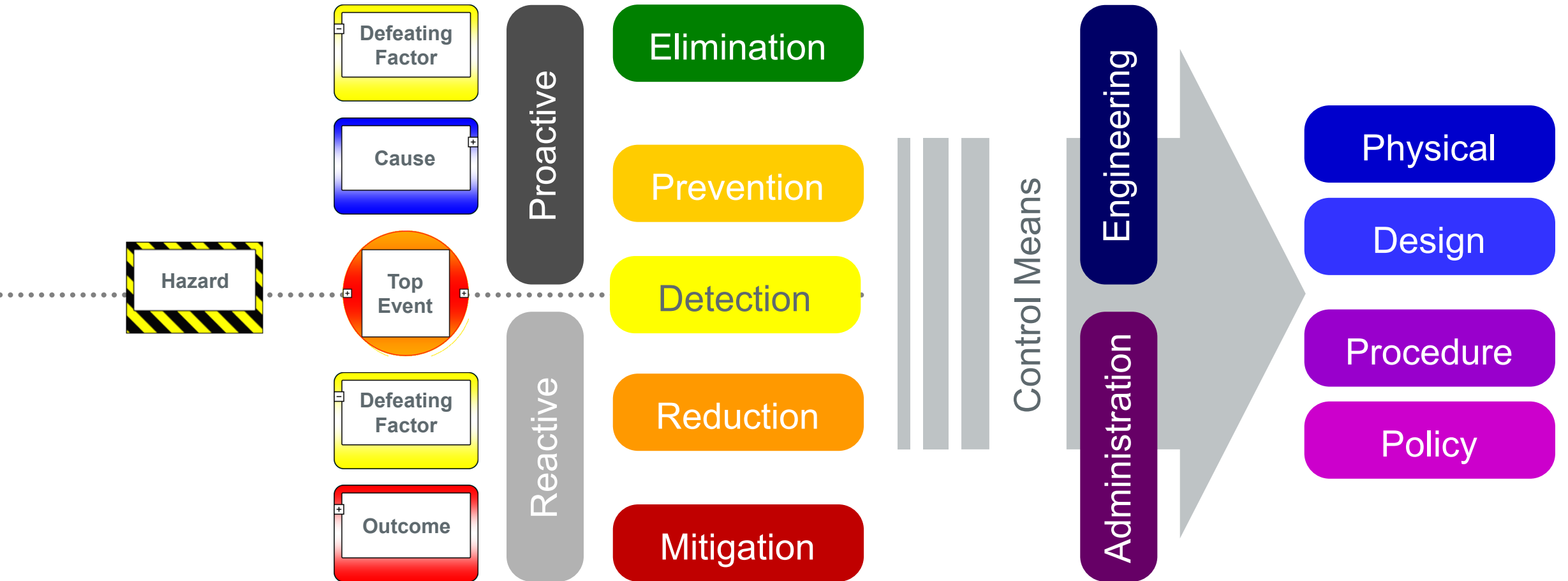
*Abating, excusing or diminution of something*

Mitigation controls lessen the significance or damage caused by a top event or outcome and will usually take effect only after these have occurred and are more a function of dealing with severity than likelihood.

The objective of mitigation controls is primarily related to outcomes.

# Complexity of Control

*Control 'means'*



# Control Means

Engineering

Physical

Design

*The discipline or act of applying scientific knowledge to practical problems*

This control means can be further divided into several sub elements such as substitution, isolation, and separation.

Engineering controls are characterized by physical objects, equipment, and technical design.

# Control Means

Administration

Procedure

Policy

*The persons and processes involved in providing organizational governance*

This control means involves processes, procedures, safe work practices, operating procedures, organizational rules, housekeeping, staff rotation, standards, warning signs, training, codes of practice, etc.

Administration controls are characterized by the activities that people do and the rules that they observe.

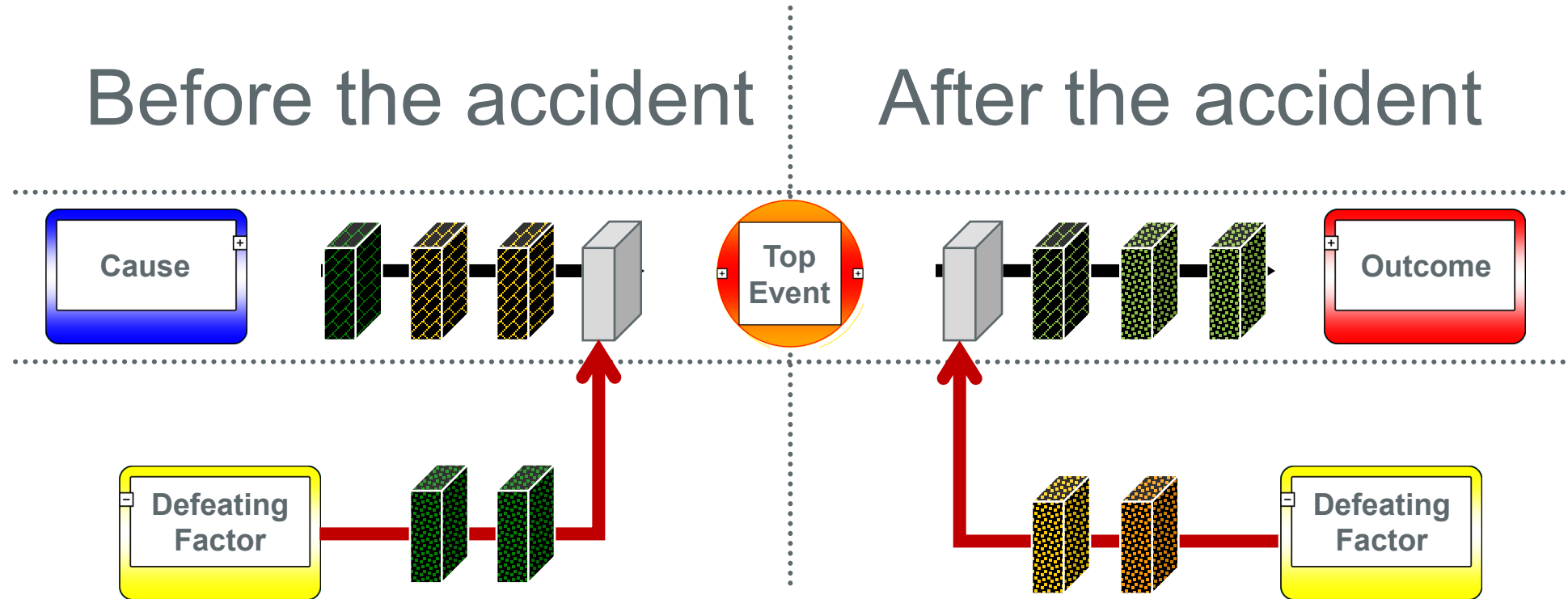
# Applied Hierarchy of Controls

## Control Objective



## Control Means

# Control Effect Time Context



Continuously before and after the accident

# Control Effectiveness

How effectively will controls work



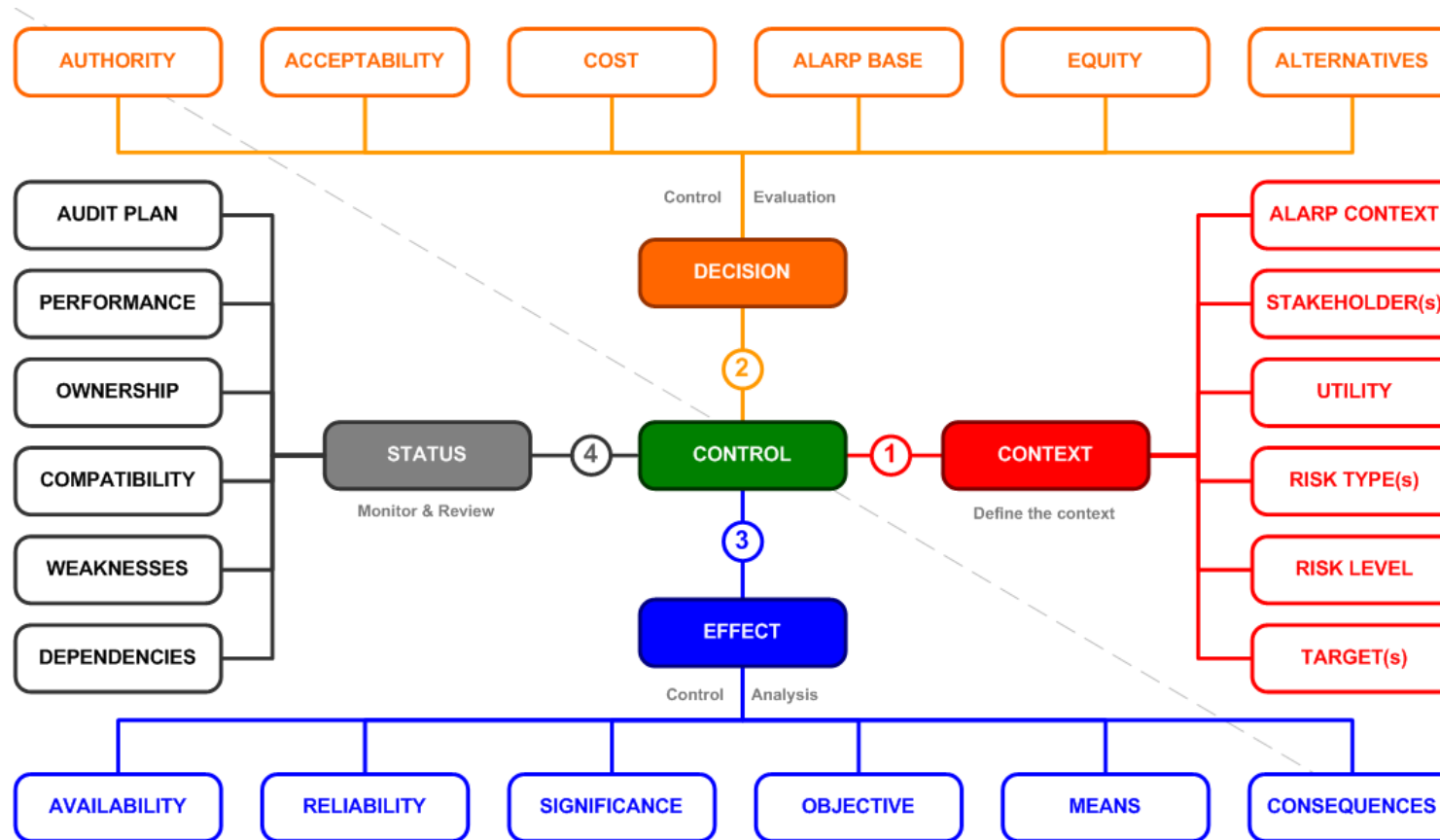
# Control Effectiveness

*How good a control effect will be at modifying a risk*

*“It is generally agreed that the value of reliability assessment lies not in the figure obtained for system reliability, but in discovery of the ways in which reliability can be improved”*



# Qualitative Control Effectiveness



## Effect (Planned)

- Availability
- Reliability
- Significance
- Consequences

## Status (Current)

- Performance
- Compatibility
- Weaknesses
- Dependencies

In BowTie analysis, effectiveness is how good a control effect will be at modifying a risk









		ASSURANCE (Availability & Reliability)				Description of the aspect of control effectiveness	Describe the weaknesses (if any) that were identified during the assessment
		Very Poor	Poor	Good	Very Good		
IMPACT (Impact & Duration)	Very Good	7	11	15	16	<i>Availability: Will the control exist and be available when and where you need it?</i>	
	Good	5	9	13	14	<i>Reliability: Will the control work like it was designed and intended?</i>	
	Poor	2	4	10	12	<i>Impact: What will be the scale and size of effect if this control works perfectly?</i>	
	Very Poor	1	3	6	8	<i>Duration: What will be the duration or time that the control will have its effect?</i>	

Effectiveness	Required Remedial Action Plan	Describe or illustrate the context in which control effectiveness was assessed
Very Poor	<i>This control is not acceptable for the management of risks. It requires remedial action(s) or should not be included in the risk management plan.</i>	Cause — Control — Effect
Poor	<i>This control should be reviewed further to determine if options are available to improve its effectiveness before it is included in the risk management plan.</i>	
Good	<i>This control is acceptable, however there may still be remedial actions available to treat any identified weaknesses if they are reasonable and practicable.</i>	
Very Good	<i>The effectiveness of this control is at an acceptable level and no further action is required.</i>	

In BowTie analysis, effectiveness is how good a control effect will be at modifying a risk



Rating	Availability	Reliability	Human Factor		
<b>++</b>	In place and used all of the time	<b>Very reliable</b> (100%)	No human involvement, simple instructions, easy to operate, intuitive, proven operator performance. Error practically impossible.	<b>Very effective</b>	
<b>+</b>	In place and used most of the time (approx. > 90%)	<b>Reliable</b> (> 95% but < 100%)	Clearly defined task, defined operating procedures, person is trained and experienced. Error conceivable but very unlikely.	<b>Effective</b>	
<b>0</b>	In place and used inconsistently (approx. > 50% but < 90%)	<b>Fairly reliable</b> (> 75% but < 95%)	Operating under stress, multi-tasking, complex procedures, difficult to operate, person is trained but errors considered possible.	<b>Fairly effective</b>	
<b>-</b>	Not permanently in place and used infrequently (approx. < 50%)	<b>Unreliable</b> (> 50% but < 75%)	Operating under high stress, complex or unclear procedures, inadequate training. Errors considered quite possible.	<b>Ineffective</b>	
<b>--</b>	Not in place and never used	<b>Very unreliable</b> (< 50%)	Personnel unfamiliar with the task, very complex procedures, no operator training. Errors can be expected or emergency situation.	<b>Very ineffective</b>	
<b>?</b>	Unknown	Unknown	Unknown	<b>Unknown</b>	

In BowTie analysis, effectiveness is how good a control effect will be at modifying a risk



# Control Responsibility

Who is responsible for controls



# Who is Really Responsible

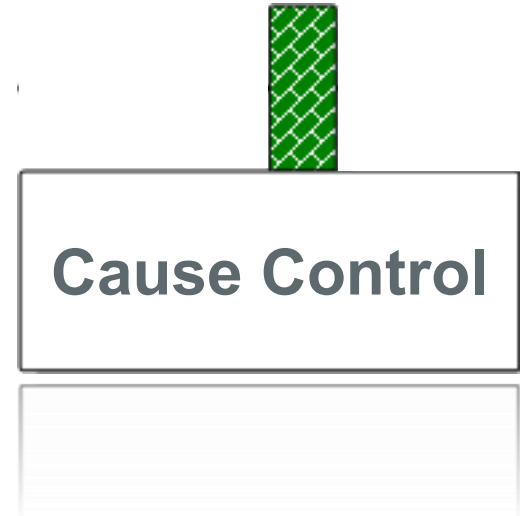
- **Accountable** (Managers)
- **Responsible** (Supervisors)
- **Operational** (Workers)



The control owner (responsible person) is the position that has day-to-day awareness (line-of-sight) of the control and the knowledge and authority to ensure that the control is effectively implemented by the operational people.

# Step 5 - Cause Controls

*A control that modifies risk by modifying causes or top events*



# Cause Control Examples

Physical

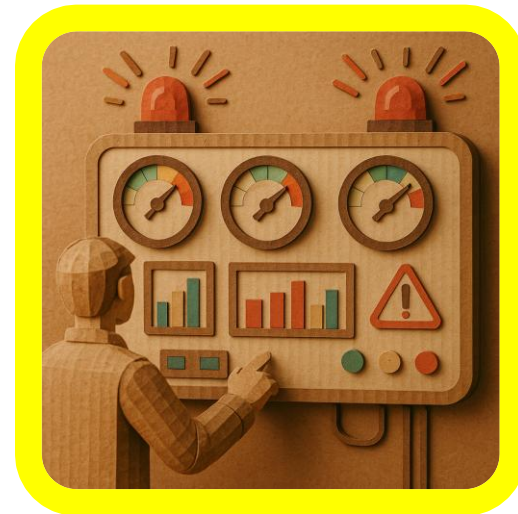
Elimination



Equipment  
Guards and  
Barriers

Design

Detection



Equipment  
Monitoring  
Systems

Procedure

Prevention



Safe Work  
Procedures

Procedure

Prevention



Checklists and  
Work Permits

# Cause Control Good Practices

- Quickly identify all controls first, then assess them
- Apply the control hierarchy sequentially
- Focus on eliminating causes, then preventing top event
- Make sure the effect is delivered before the top event
- Adjust the cause(s) if necessary to fit the controls

Use these good practices when doing your BowTie analysis





**Cause  
Controls**

Identify the control(s) associated with the causes of a loss of pilot control over helicopter motion and direction during landing or departure at an offshore oil and gas facility

Learning exercise (5 minutes)



# Step 6 - Outcome Controls

*A control that modifies risk by modifying the likelihood or severity of outcomes and consequences*



# Outcome Control Examples

Physical

Detection



Emergency Alarms

Physical

Reduction



Worker PPE

Physical

Mitigation



First Aid Equipment

Physical

Mitigation



Spill Clean Up Equipment

# Outcome Control Good Practices

- Has no effect upon the top event
- Modifies the likelihood or severity of outcomes
- Consider targets being protected by the controls
- Effect also delivered after the outcome occurs
- Adjust the outcome(s) if necessary to fit the controls

Use these good practices when doing your BowTie analysis





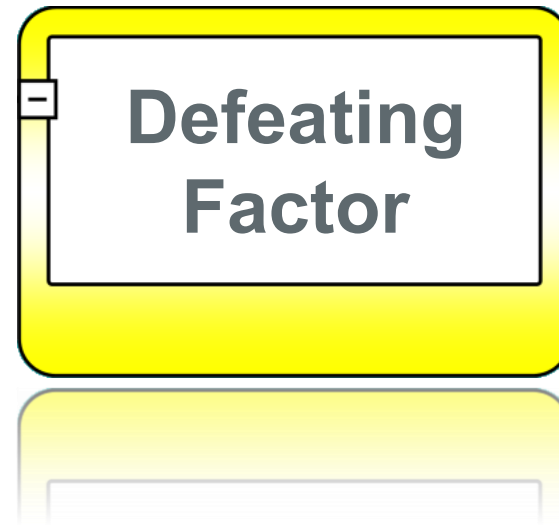
**Outcome Controls**

*Identify the control(s) associated with the outcomes of a loss of pilot control over helicopter motion and direction during landing or departure at an offshore oil and gas facility*



# Step 7 - Defeating Factors

*Conditions that defeat or reduce the effectiveness of cause and outcome controls*



# Comparative Failure Analysis

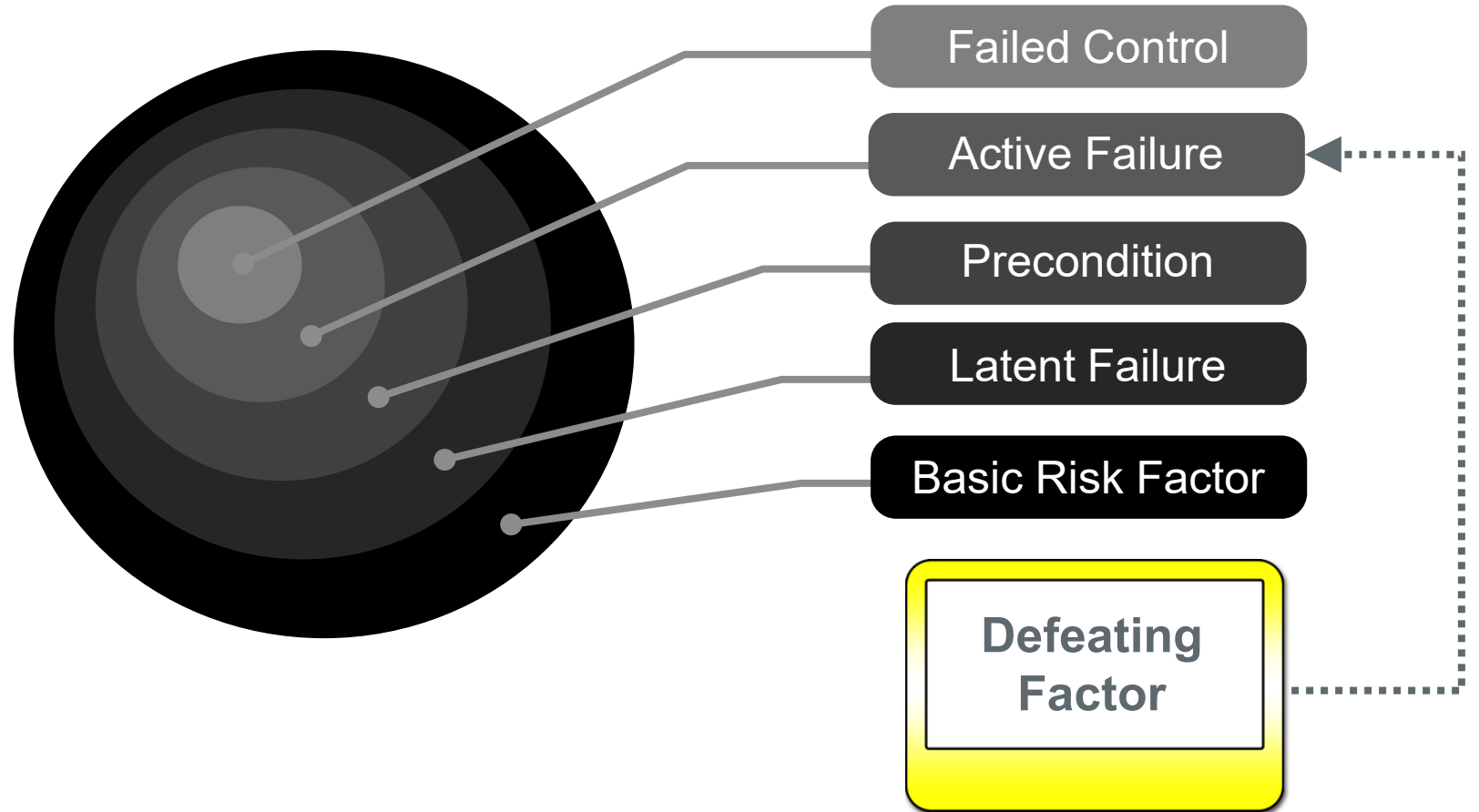
- Failure modes, effects and criticality analysis
- Cause consequence analysis
- Fault tree analysis
- Bouncing failure analysis

BowTie analysis uses a very limited and simplistic representation of why systems (controls) fail

# Anatomy of a Control Failure

In bowtie analysis defeating factors should not extend too far beyond the active failure which is directly related to the failure of the related control.

Underlying causes for failure can be analysed via other methods.



In BowTie analysis, defeating factors are the conditions that defeat or reduce the effectiveness of controls



# Defeating Factor Categories



Human Factors



Mechanical Failures

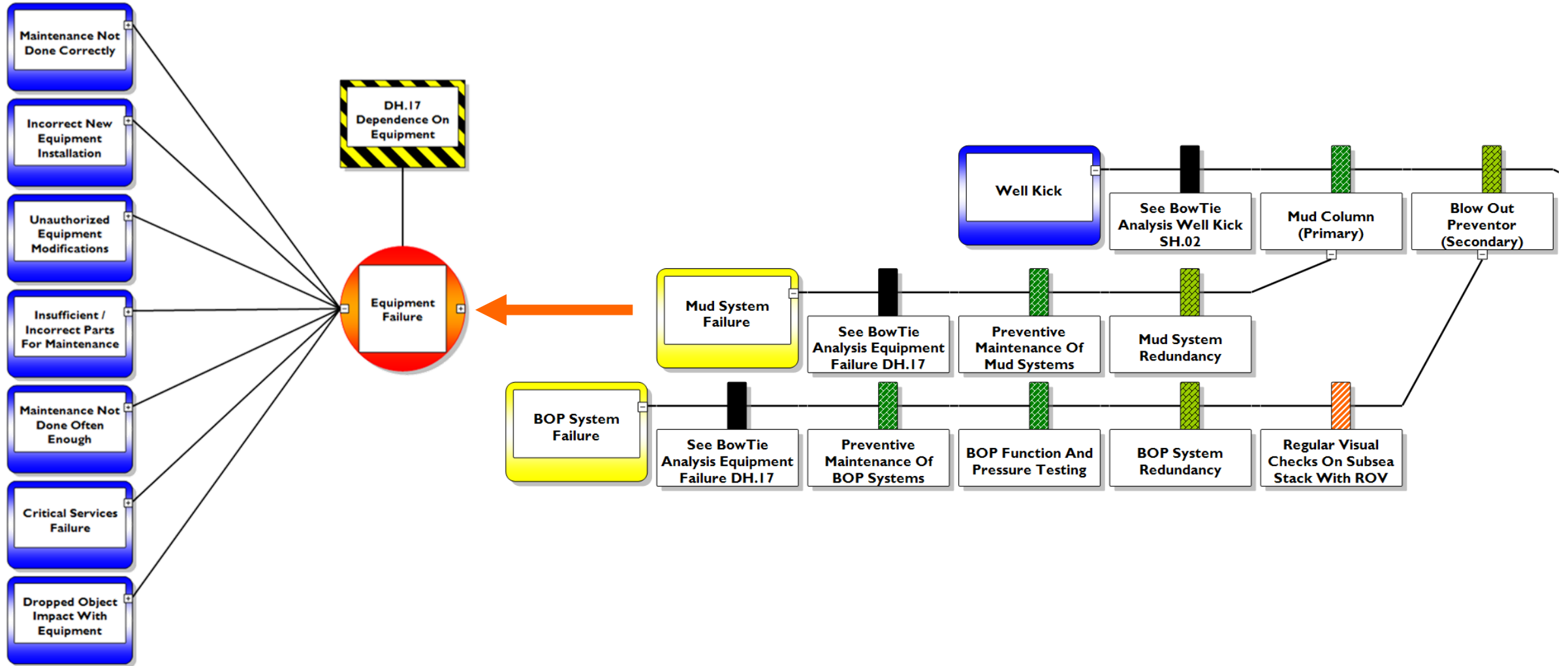


Abnormal Conditions



Loss of Services

# Causality Categories and Chaining



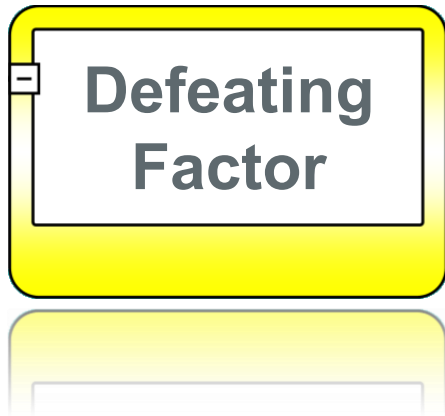


# Defeating Factor Good Practices

- Defeating factors need to be credible
- Learn from previous incidents
- Focus effort on the critical controls
- They do not cause top events or outcomes
- Do not nest defeating factors within defeating factors
- Develop general bowties for underlying generic issues

Use these good practices when doing your BowTie analysis





*Identify the defeating factor(s) associated with the outcome controls for a helicopter ditching into the ocean next to the facility outcome*



# Step 8 - Defeating Factor Controls

*A control that modifies risk by managing the factors which reduce the effectiveness of cause and outcome controls*



# Defeating Factor Control Examples

People



Training and Induction



Supervision and Mentoring



Qualifications and Certification



Auditing and Verification

Plant



Maintenance and Repairs



Inspection and Testing



Redundancy and Spare Parts



Design and Specifications

# Defeating Factor Control Good Practices

- These should be the core of the HSEMS
- Focus on the defeating factor
- They deliver their effect continuously
- They do not modify the causes or outcomes
- Avoid repetition by using generic BowTie models

Use these good practices when doing your BowTie analysis



**Defeating  
Factor Controls**

--

*Identify the control(s) associated with the defeating factors associated with the outcome controls for a helicopter ditching into the ocean next to the facility*





## *Finally, some advice ...*

- Establish and use standard terminology
- Establish and use a robust methodology
- Think outside of the three-tier 'BowTie' model
- Keep elements in the correct 'time-zone'
- Divide analysis into 'model' and 'controls'
- Never involve non-risk experts in the 'model'
- Use sophisticated causal analysis methods
- Use an escalating outcome analysis method
- Use an abstracted systems approach for controls
- Be economical, specific, and standardised in your use of language when defining events and controls

# Thank You

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