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Introduction to the CCPS / Energy Institute Process Safety book:
"Bow Ties in Risk Management"

Presentation by Mark Boult and Paul McCulloch

CGE Network event 2018
27-28 September, Amsterdam – NL
www.cgerisk.com/networkevent2018

Good to see you at our presentation

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Hi

- Paul McCulloch
- CGE

- Mark Boult
- DNV GL

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# What we will cover today

- Summarise the book's key messages – Mark Boult
  - Why it was decided to write a book, and what it covers
  - Terminology
  - Recommended process for constructing a bow tie
  - Rules for barriers
  - Barriers vs degradation controls
  - Human errors in bow ties
  - Effectiveness vs condition
  - Uses of bow ties
- Implementing the key messages of the book in BowTieXP – Paul McCulloch

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Why it was decided to write a book, and what it covers

BOW TIES IN RISK MANAGEMENT

A Concept Book for Process Safety

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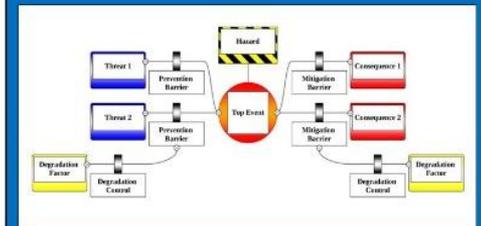
Why a "Bow Tie" book?

- Confusion about who (and what) bow ties are for

- No generally accepted methodology and terminology

- Some typical problems with existing bow ties:

  - Structural errors: e.g. degradation controls shown as barriers

  - Lack of rigour in constructing bow tie elements:

    - Hazard or Top Event description vague, or confused with Consequence

    - Incomplete barriers: barrier elements listed as 'the barrier'

    - Management System elements included as 'barriers'

  - 'Human and Organisational Factors' confused and ineffective

  - Unfair criticism that bow ties over-simplify incident causation

> **"Well constructed bow ties, which are clear and enable easy communication, can give the impression that they are easy to create. This is not the case. Too often bow ties are created with structural or other errors which can significantly degrade their value."**

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CCPS / Energy Institute Concept Book

- CCPS decided to develop a Concept Book to capture best practice and define a methodology for bow ties.

- Energy Institute joined the project with a special emphasis on human factors

- "*Bow Ties in Risk Management: A Concept Book for Process Safety*"

  – Proposes standardized bow tie terminology and definitions

  – Explains how to:

    – Construct bow ties of high practical value, avoiding common pitfalls

    – Treat human and organizational factors in a sound and practical manner

    – Apply bow tie can be used to create high value organizational learning from incidents and audits

    – Practical application and value of bow ties in plant management and active risk management, from the control room to the board room

  – Based on current best barrier management knowledge and approaches

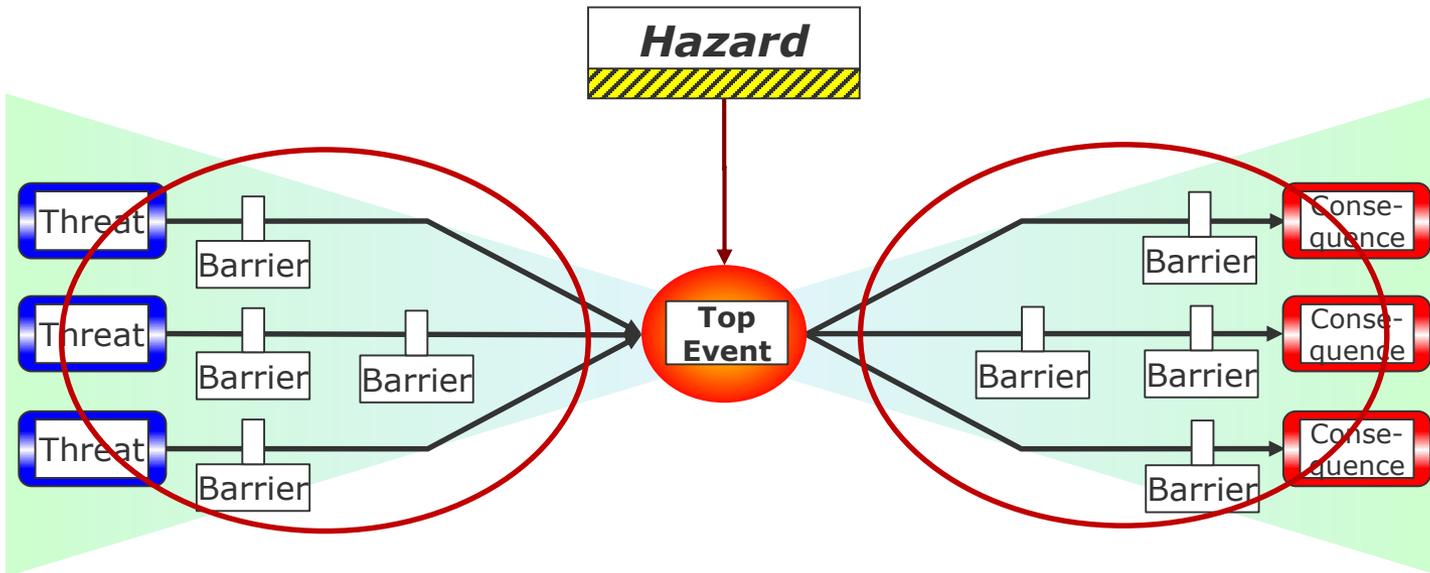 – Draws on a wealth of industry experience from well-known experts

BOW TIES IN RISK MANAGEMENT

A Concept Book for Process Safety

CCPS | energy institute | WILEY
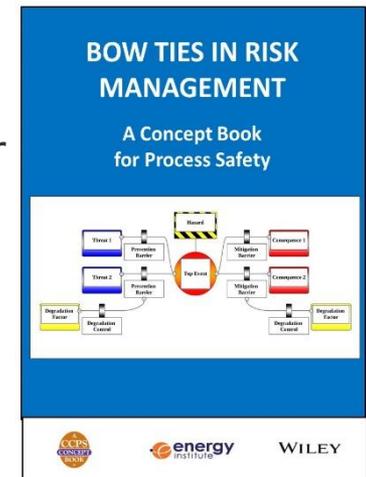
180 Pages.
Planned publication
October 2018

Terminology and recommended process for constructing a bow tie

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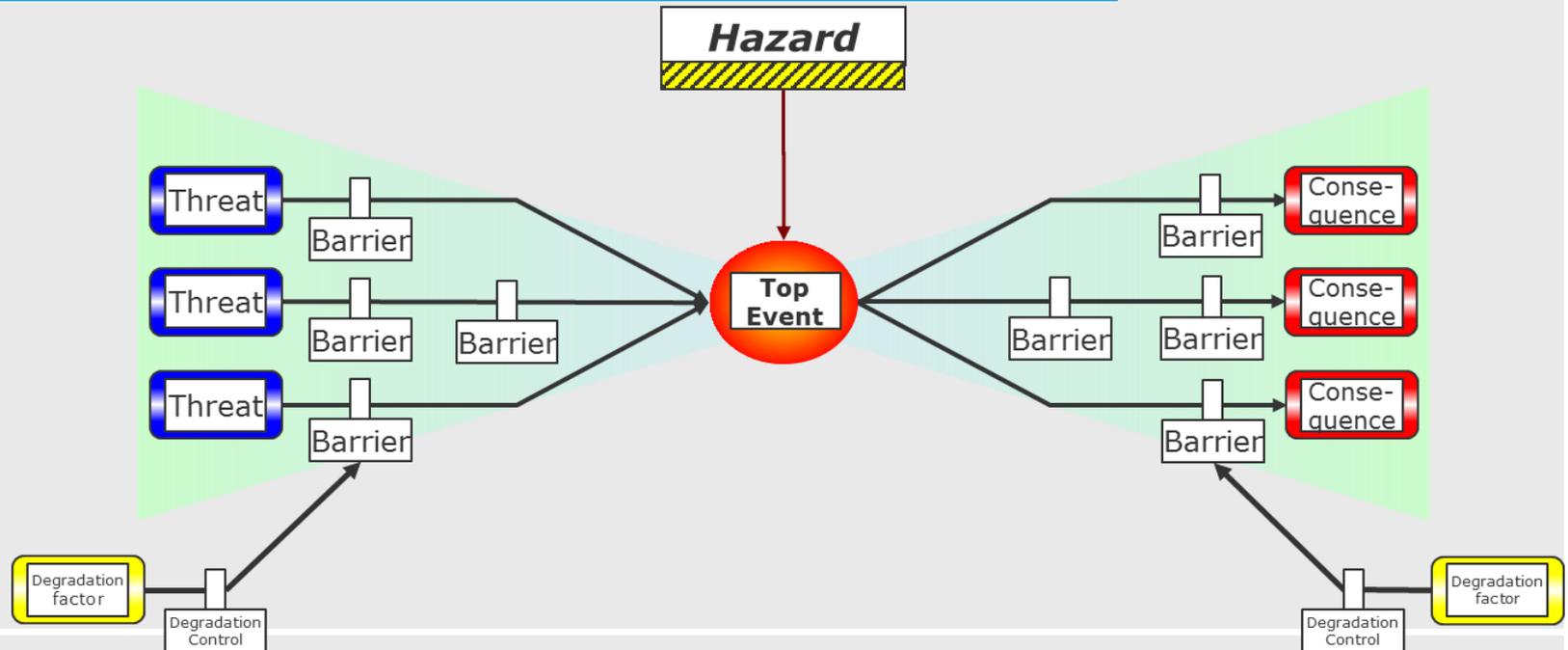
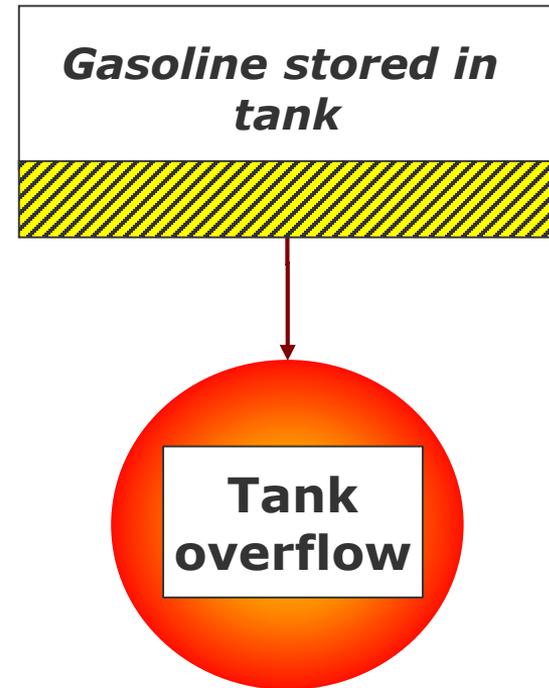# Stepping through the risk assessment process
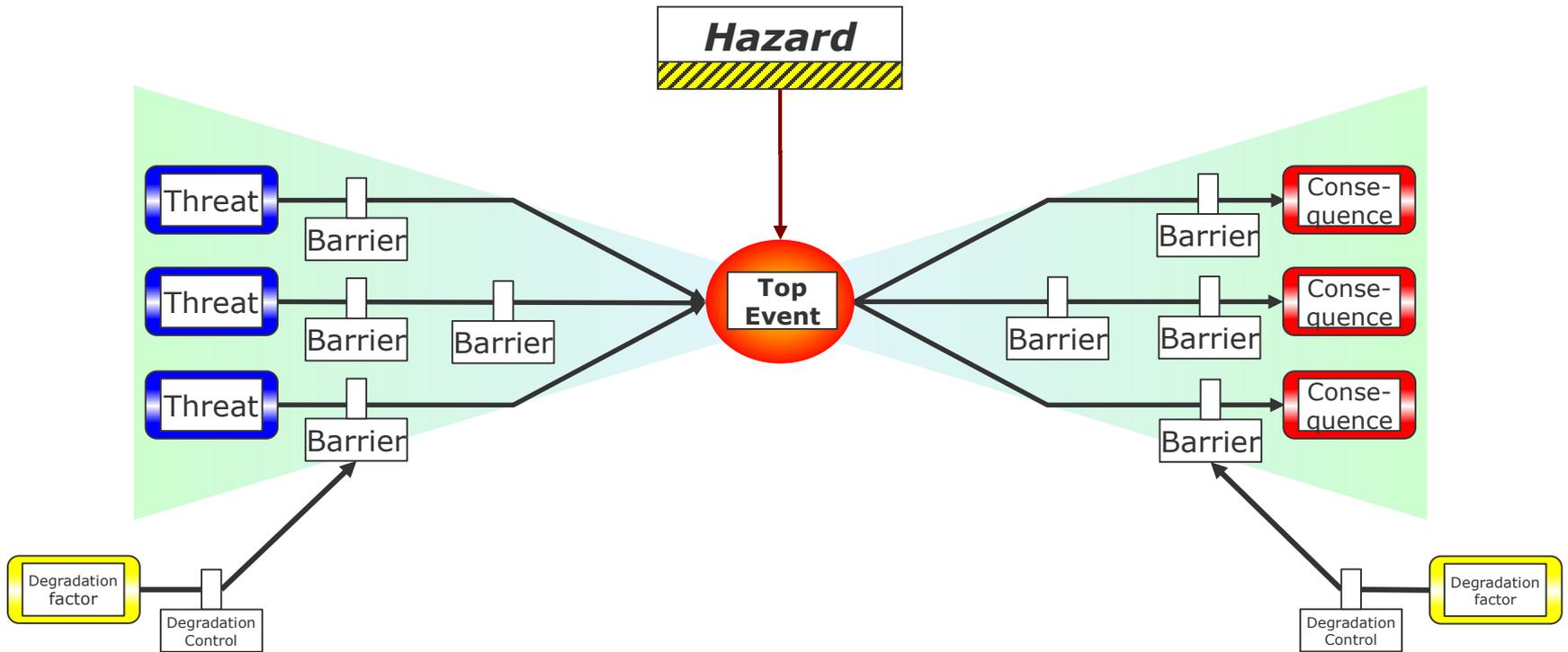
Examples and useful rules for quality in bow ties

- **Hazard** is an operational, activity or materials with the potential to cause harm
  - "What you are trying to control"
- Hazards should
  - Be specific
  - For the hazard in its controlled state
  - Can also include:
    - Situational context
    - Indication of scale
- Not always possible to define all in the box

Propane ~ Too general ✘

Pressurised Propane stored in sphere ~ Better ✔

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Examples and useful rules for quality in bow ties

- **Top event** is the moment when control over the hazard is lost releasing harmful potential

- Top event
  - Describe how / what control is lost
  - Can give an indication of scale (e.g. leak vs rupture)

- Do not define as:
  - A threat (corrosion of the tank)
  - A consequence (e.g. tank overflow and major dike fire)
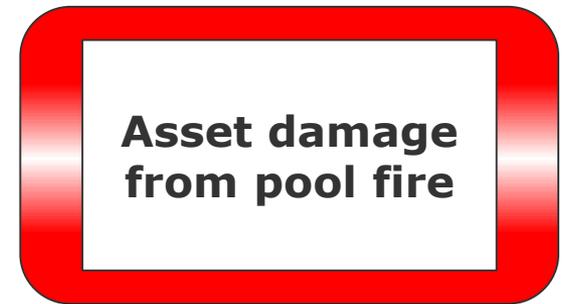- A barrier failure is not a top event

Gasoline stored in tank

Tank overflow

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Examples and useful rules for quality in bow ties

- **Consequences** direct outcome of an accident sequence that results in harm …

- Recommend defining before "threats" – this can help ensure that threats defined are those that lead to the significant consequences

- Should be defined as:

  - "Damage" due to "Event", e.g. environmental damage due to liquid spill

  - Do not be too specific in defining the consequences (e.g. differentiating injury outcomes from fatality outcomes) as the barriers are likely to be the same and the number of branches is increased
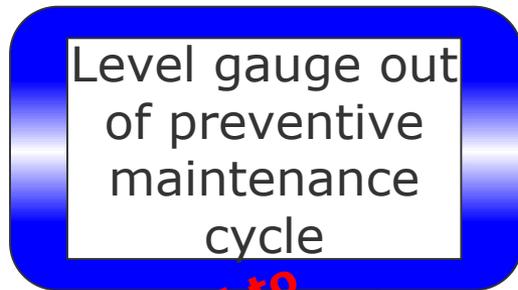
Loss of containment

Pollution

Too general ✗

Asset damage from pool fire

Good ✓

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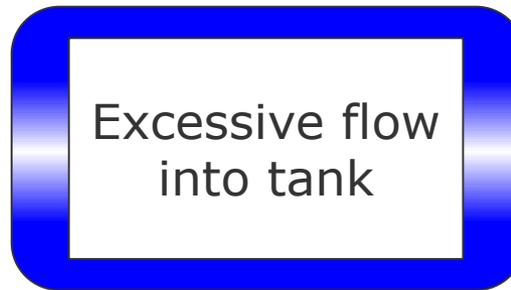**Risk Management Solutions**
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Examples and useful rules for quality in bow ties

- **Threats** initiating event that can potentially release a hazard and produce the top event
- Should be sufficient to lead to the top event by itself – be a *specific direct* cause
- Should be credible
- Should NOT be a barrier failure

Level gauge out of preventive maintenance cycle	Excessive flow into tank	Loss of containment

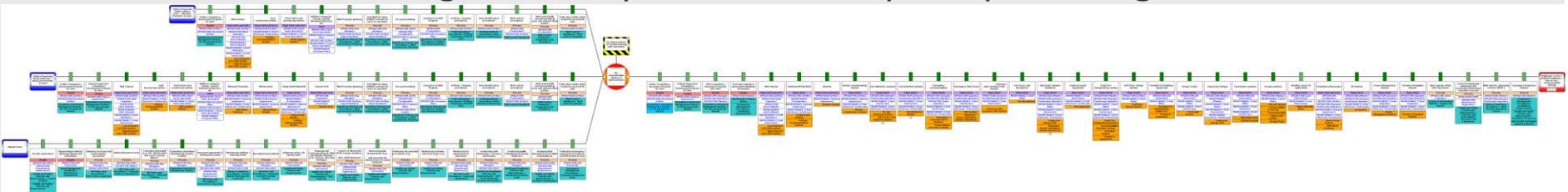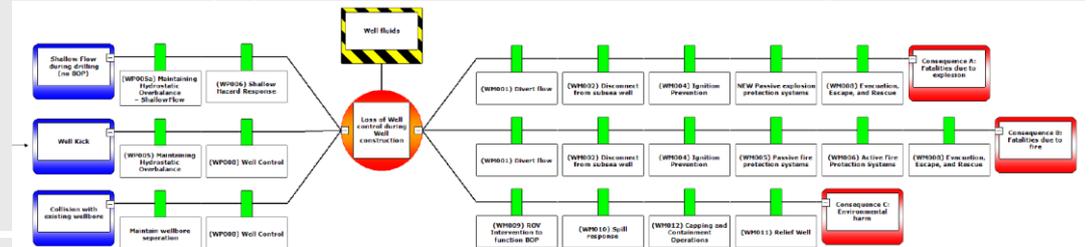*Related to possible barrier failure* ✘

Good ✔

Rules for barriers

No rules can lead to image of many barriers and perception of great risk control:

Rules help present more realistic image:

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Barrier types

Passive

Active

Human

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Barrier types - Examples

Passive
- **Passive Hardware**

Active
- **Active Hardware**
- **Active Hardware + Human**

Human
- **Active Human**

- **Continuous Hardware**

Fire Wall

Safety instrumented system

Operator activated EDS

Visual fire detection and evacuation

Cathodic protection system

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Active barrier elements deliver: detect, decide and act

Passive
- **Passive Hardware**

Active
- **Active Hardware**
- **Active Hardware + Human**

Human
- **Active Human**

- **Continuous Hardware**

Detect

Decide

Act
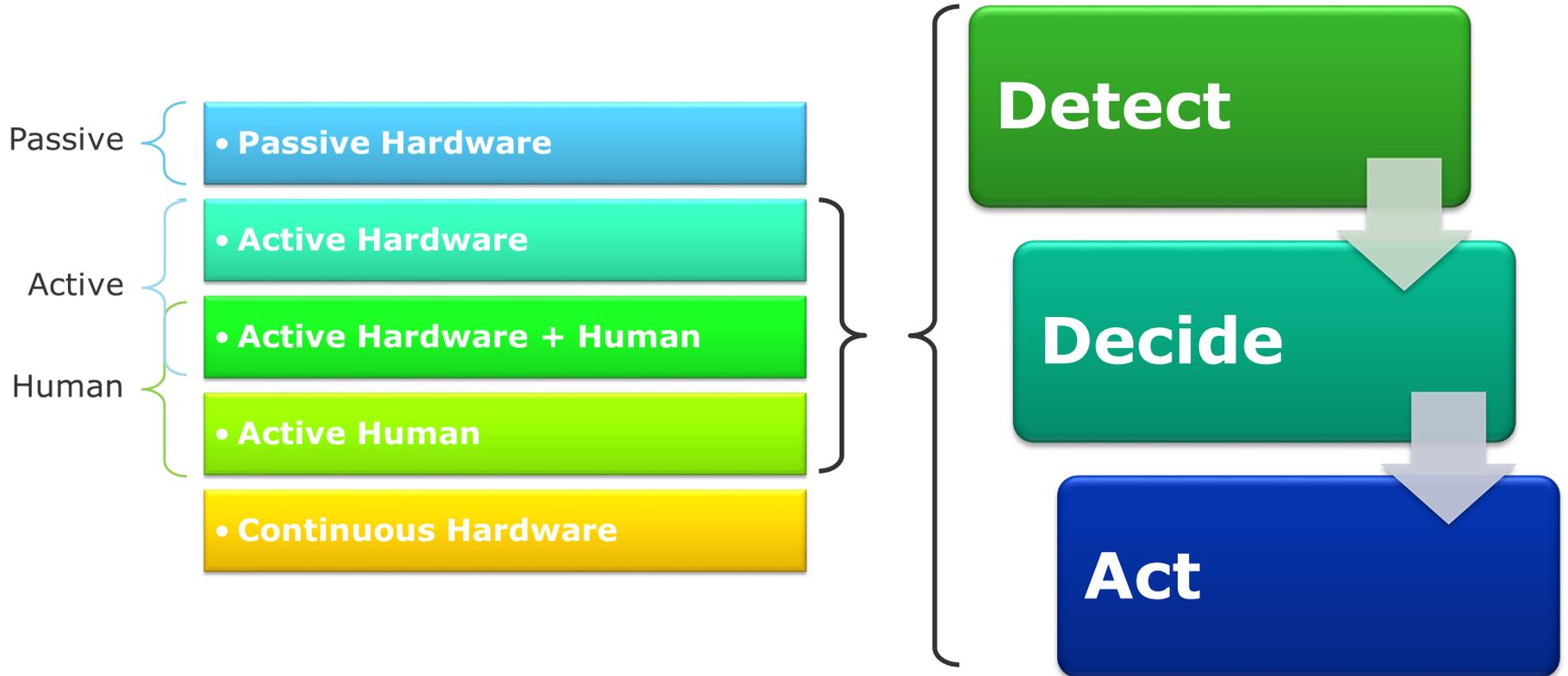
Barrier properties

Effective
- *Prevention barrier* is effective if it is capable on its own of preventing a threat developing into the top event
- *Mitigation barrier* is effective if it is capable of completely mitigating the consequences or reducing its severity

Independent
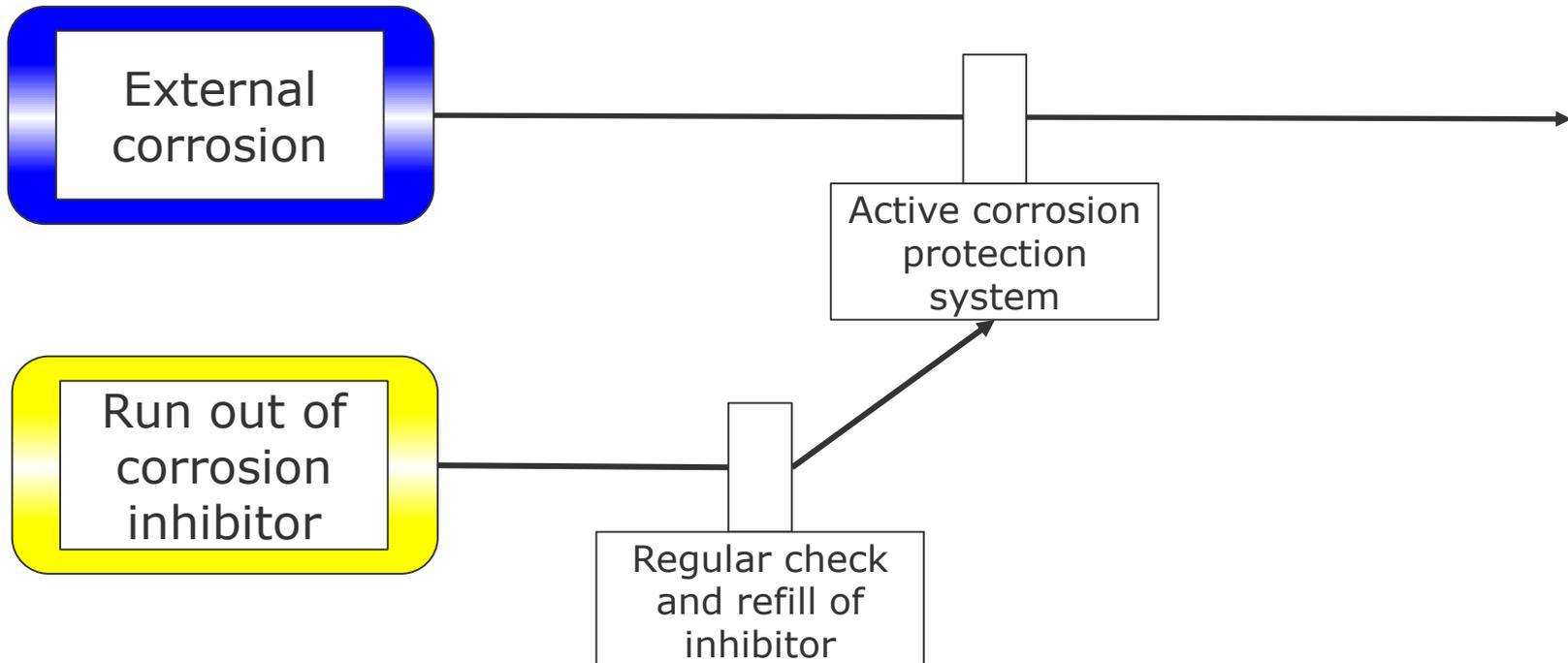- A barrier is independent if is has no common failure modes with other barriers

Auditable
- A barrier is auditable if there is a means to check that it works / delivers its functionality on demand
- Barriers can have performance standards for their functionality

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Barriers vs degradation controls

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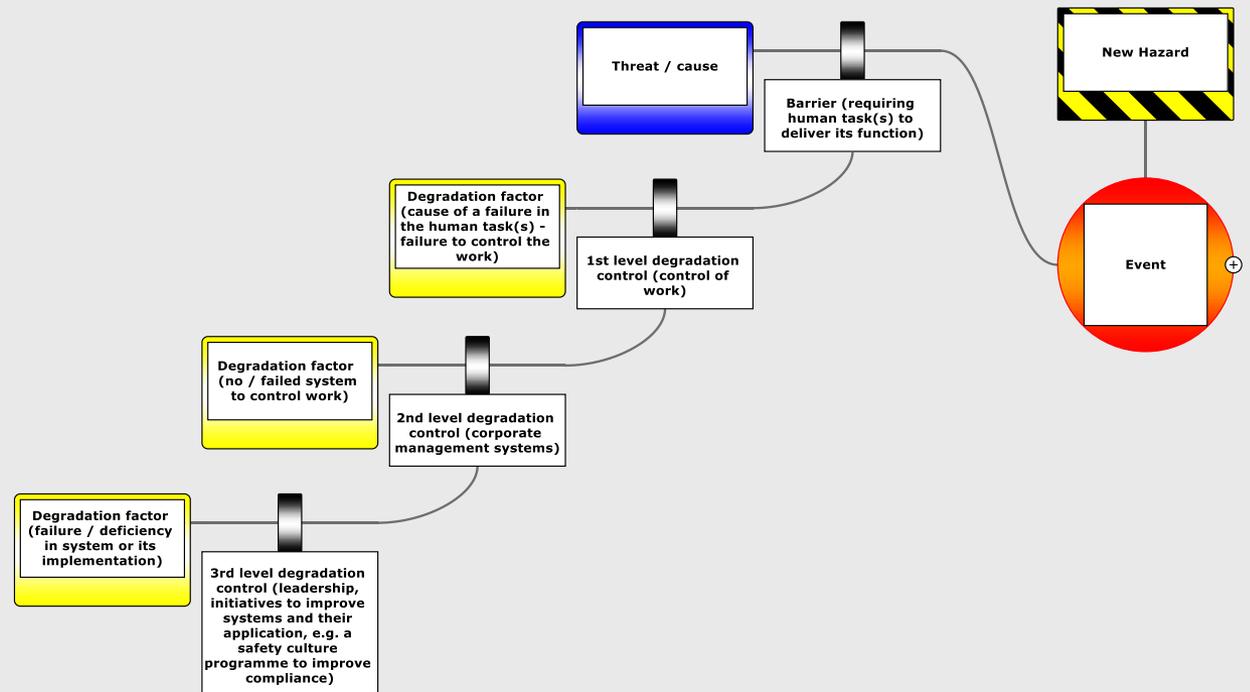Making risk understandable

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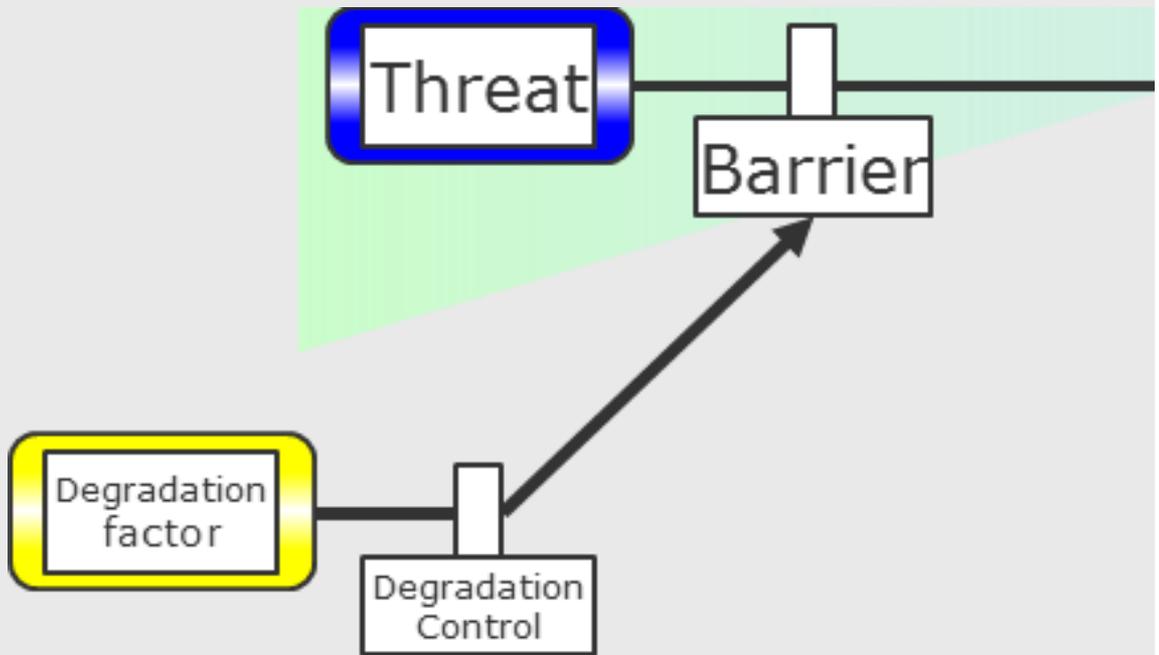
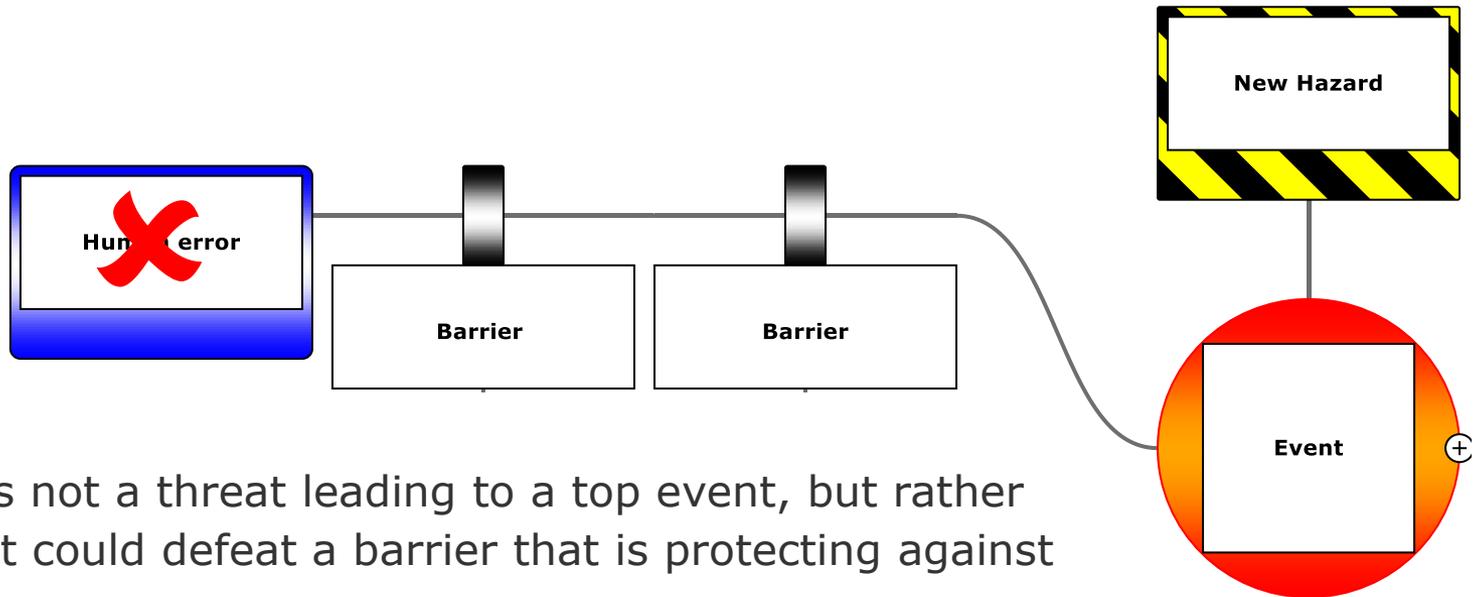# Degradation Controls (vs barriers)

- Degradation Controls are on degradation pathway (NOT on the main pathway)
- Degradation Control types as for barriers
- Degradation Controls may not meet the full requirements of barrier validity

# Where human errors fit in a bow tie

Threat / cause

Barrier (requiring human task(s) to deliver its function)

New Hazard

Degradation factor (cause of a failure in the human task(s) – failure to control the work)

1st level degradation control (control of work)

Event

Degradation factor (no / failed system to control work)

2nd level degradation control (corporate management systems)

Degradation factor (failure / deficiency in system or its implementation)

3rd level degradation control (leadership, initiatives to improve systems and their application, e.g. a safety culture programme to improve compliance)

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Do not use the words "human error" in your bow ties

- Human error is not a threat leading to a top event, but rather something that could defeat a barrier that is protecting against that top event

- Whenever someone is inclined to put 'human error' as a threat, they should challenge themselves by asking:

  – "*What is the barrier (or degradation control) that this error would defeat*"?

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Do not use the words "human error" in your bow ties

- A non-specific degradation factor leads to a non specific degradation control

New Hazard

Threat

Barrier

Barrier

Event

Human error

Degradation control

Human error

Degradation control
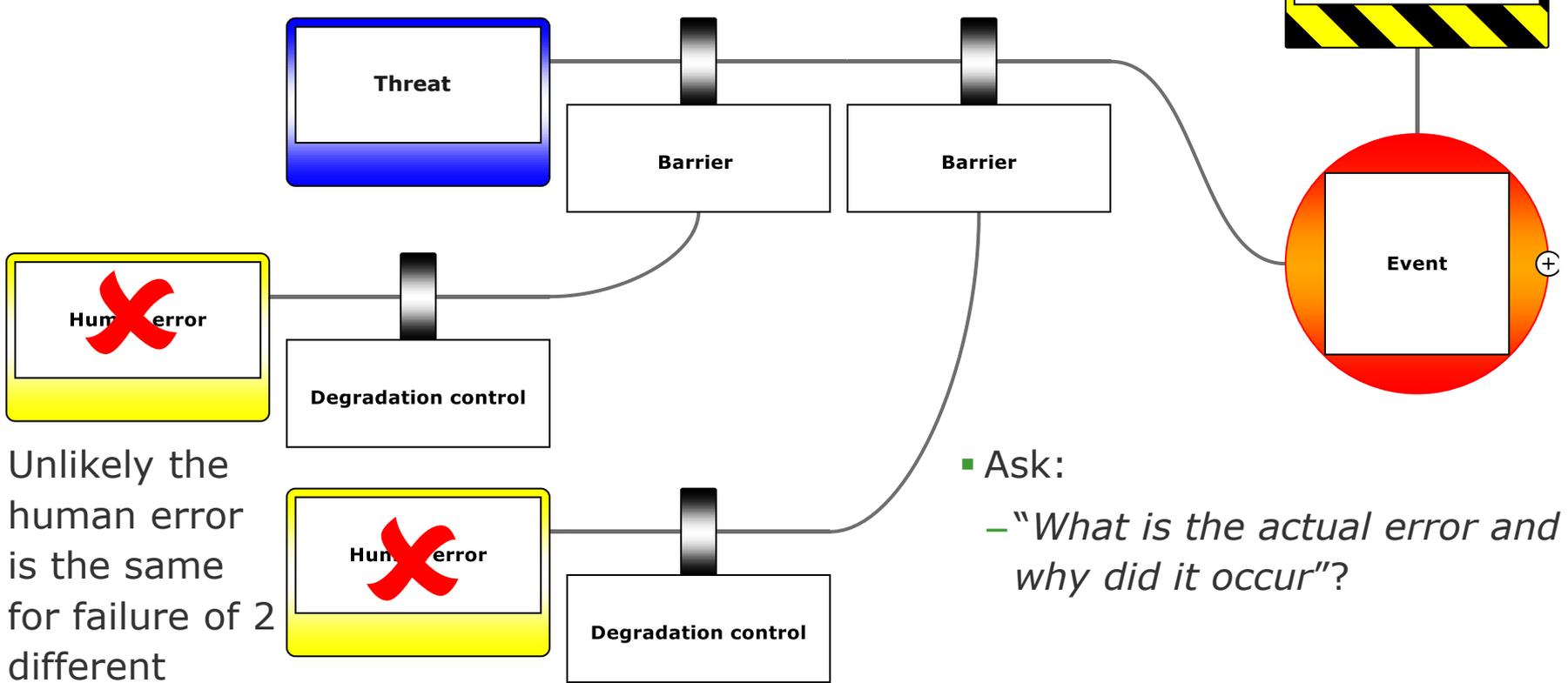
- Unlikely the human error is the same for failure of 2 different barriers

- Ask:
  - "*What is the actual error and why did it occur*"?

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Model for including human error in a bow tie

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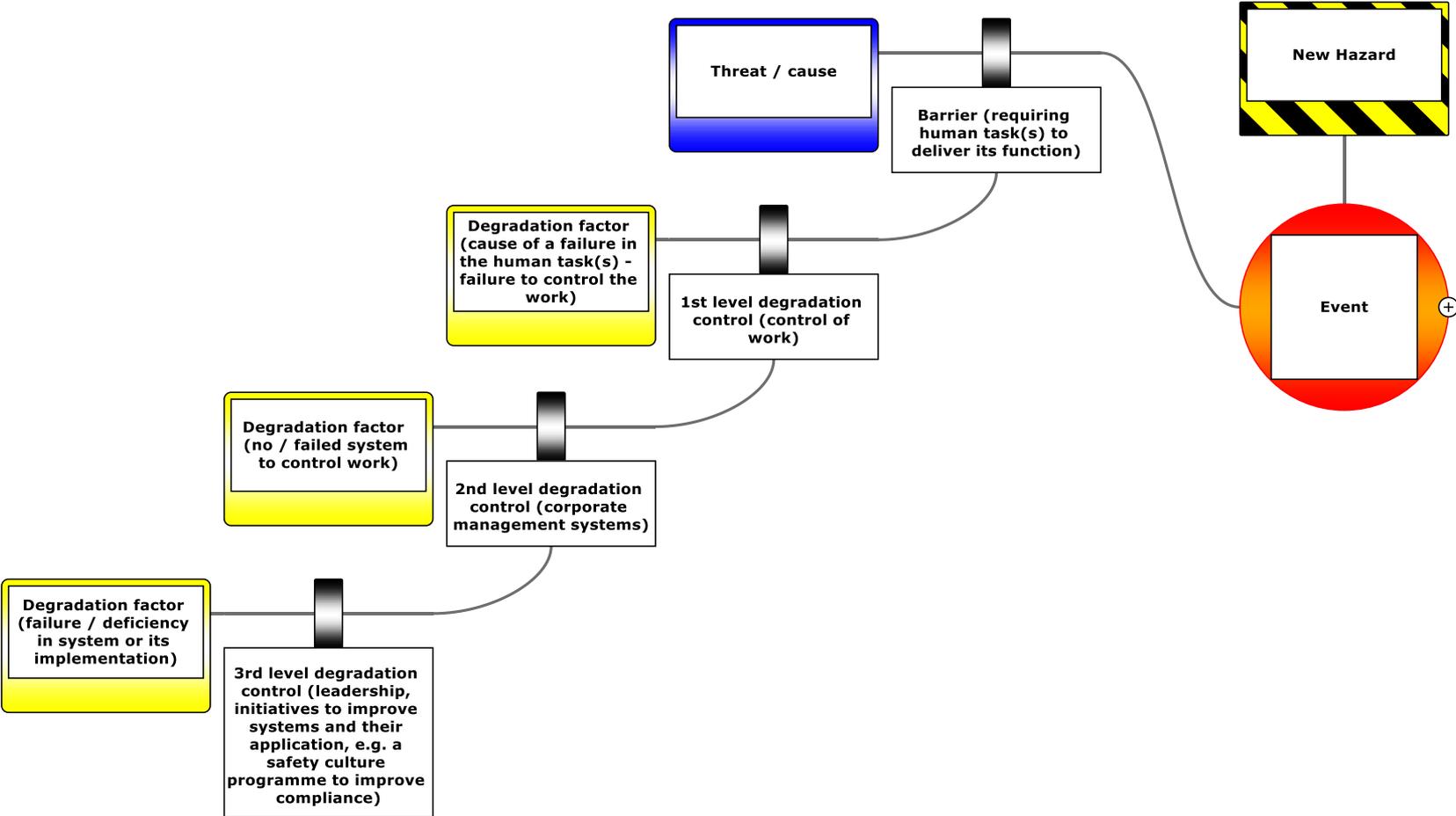
Example using model for including human error in a bow tie

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Effectiveness vs condition

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Effectiveness vs condition
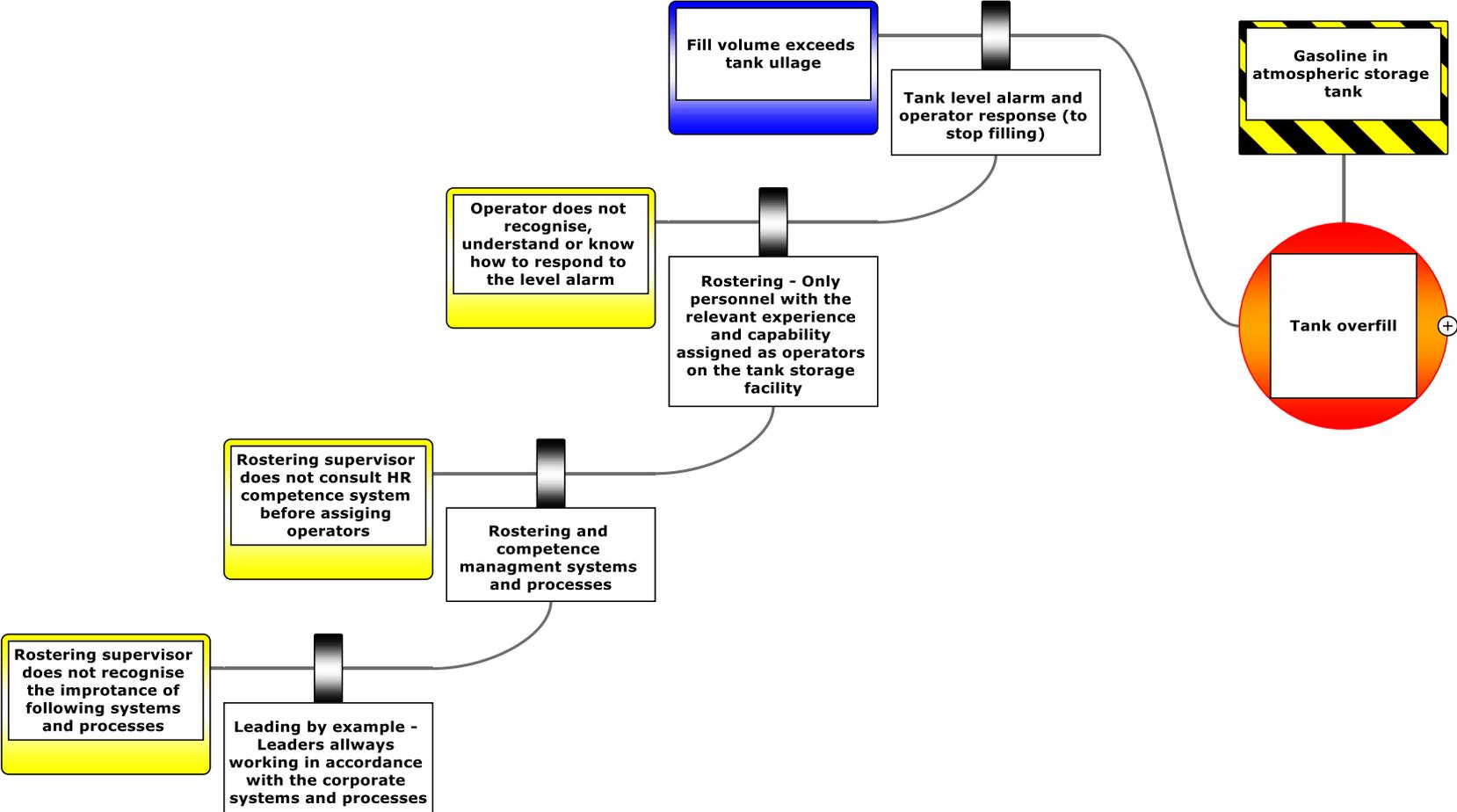
- The guidance clearly explains the difference between effectiveness vs condition

Effectiveness

- The initial effectiveness of the barrier – "how well each barrier performs"
- Design intent / performance standards set required effectiveness:
  - Functionality
  - Reliability, availability and survivability
- Some barriers will be naturally more effective than others

Condition / state

- How well is the barrier performing vs its required performance (i.e. its design intent / performance standards)?
- Degradation affects the barrier condition

Barrier A	Barrier B	Barrier C	Barrier D
Very effective PS	**Moderately effective PS**	**Very effective PS**	**Effective PS**
Slightly degraded	**Working as intended**	**Moderately degraded**	**Currently out of use**

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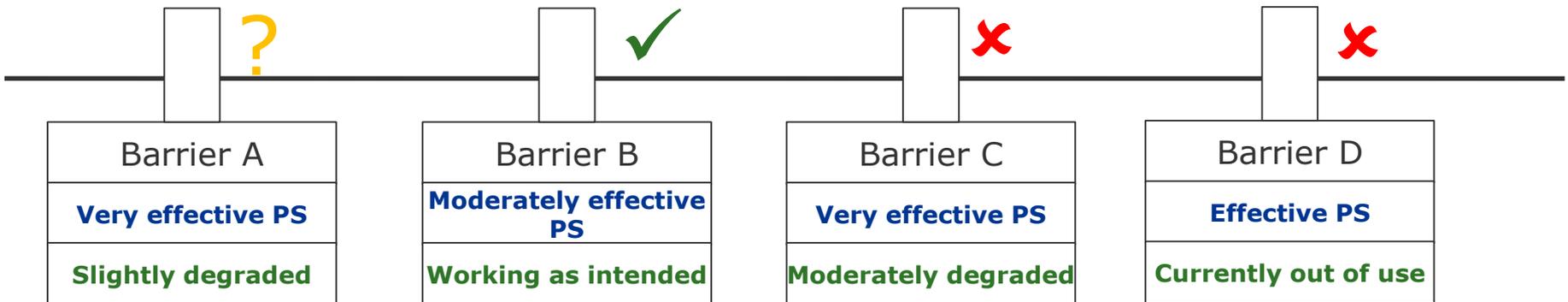
Communicating barrier effectiveness

- Possible colour coding for barrier "effectiveness" (design or current / at a moment in time)

Effectiveness name	Effectiveness (design or current – must define which)	Colour code
A	Barrier to prevent event or prevent or mitigate the consequence >99.9% (on demand / in operation)	Dark blue
B	Barrier to prevent event or prevent or mitigate the consequence >99% on demand (on demand / in operation)	Blue
C	Barrier to prevent event or prevent or mitigate the consequence >90% on demand	Light blue
D	Barrier to prevent event or prevent or mitigate the consequence <90% on demand	Very light blue
Unknown	Unknown	White
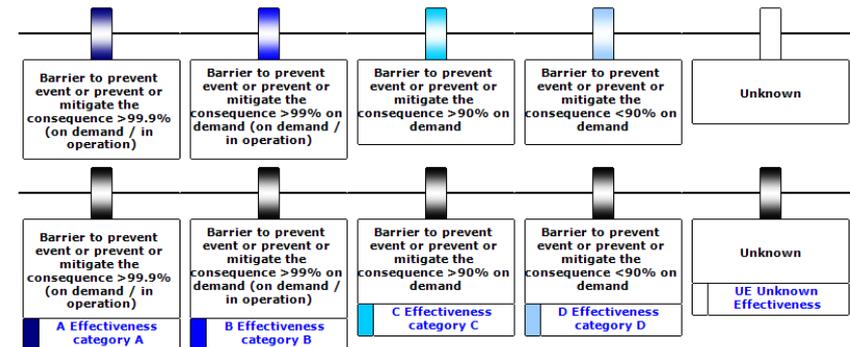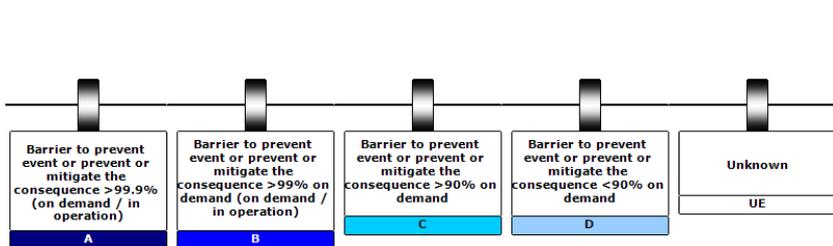
Communicating barrier condition

- CCPS suggested colour coding for barrier "condition" (current / at a moment in time)

Condition name	Condition description	Colour code
Good / excellent	Condition assessed to be such that the barrier is performing at / above it's design (PS) effectiveness	Green
Slightly degraded	Condition assessed to be such that the barrier is performing slightly below design (PS) effectiveness	Yellow
Moderately degraded	Condition assessed to be such that the barrier is performing well below design (PS) effectiveness	Red
Out of service (significantly degraded)	Condition assessment finds the barrier is not in place, turned-off, deactivated or fully degraded	Black
No data	Unknown	White

PS = Performance standard

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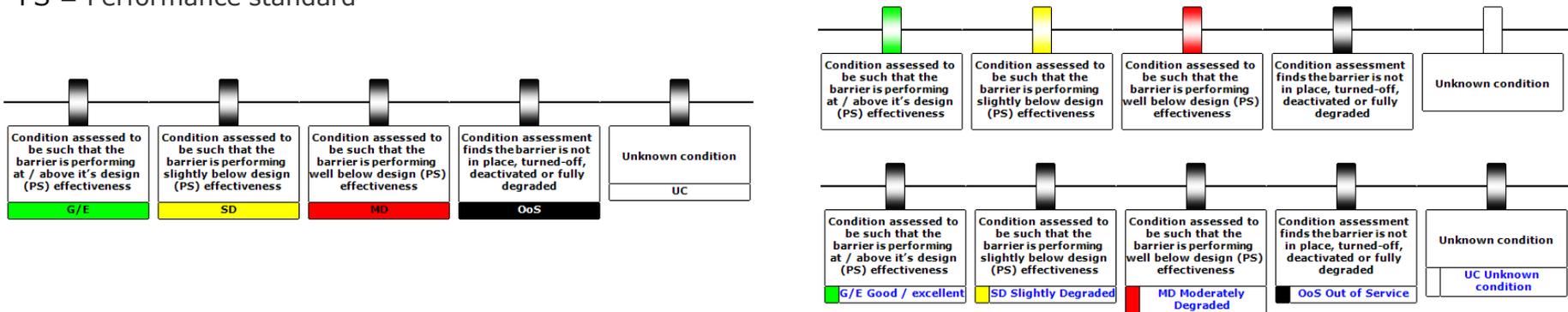
Design PS (initial?) effectiveness

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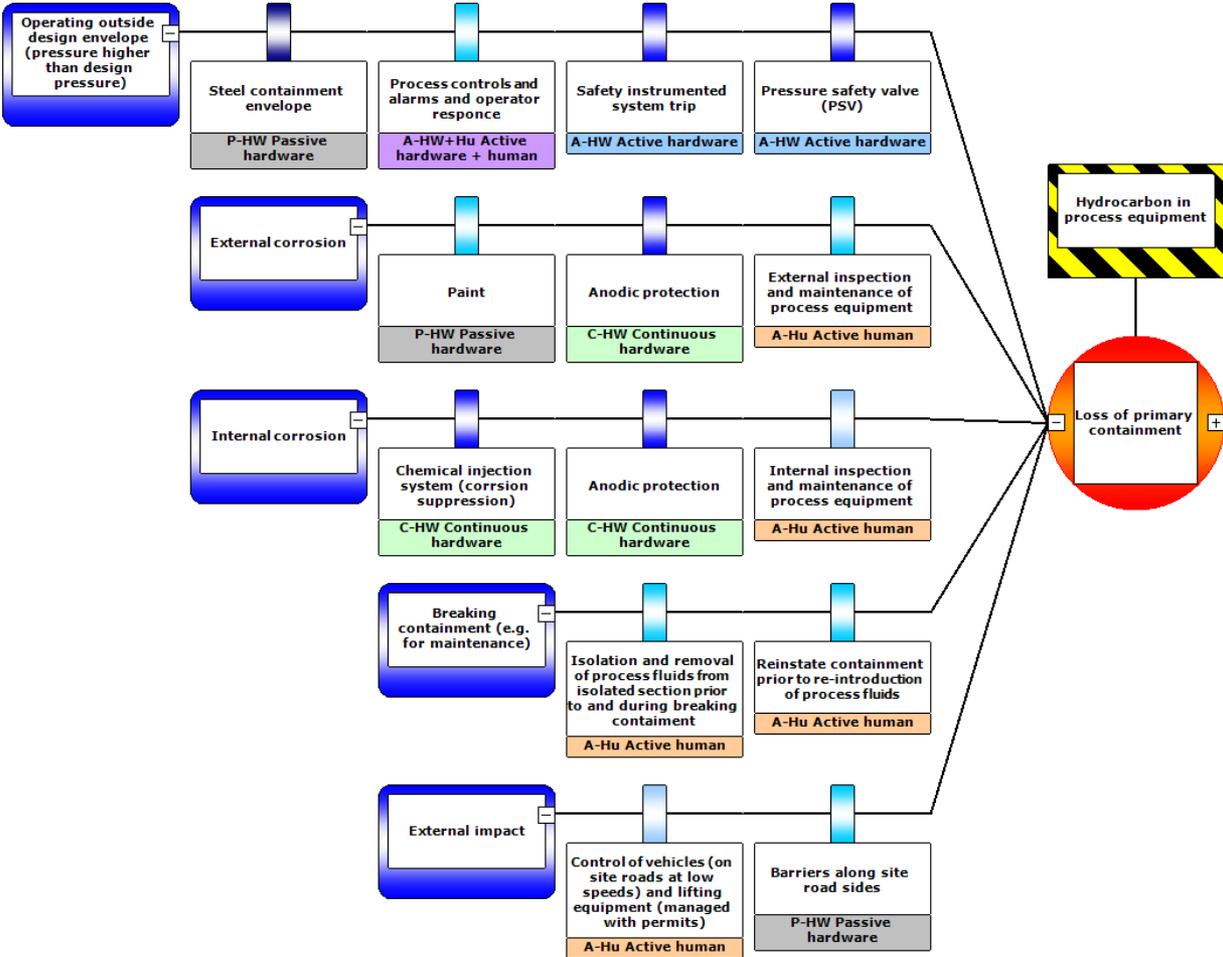
Initial (ideal / expected) state condition

Barrier condition is dynamic

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Current understanding of condition
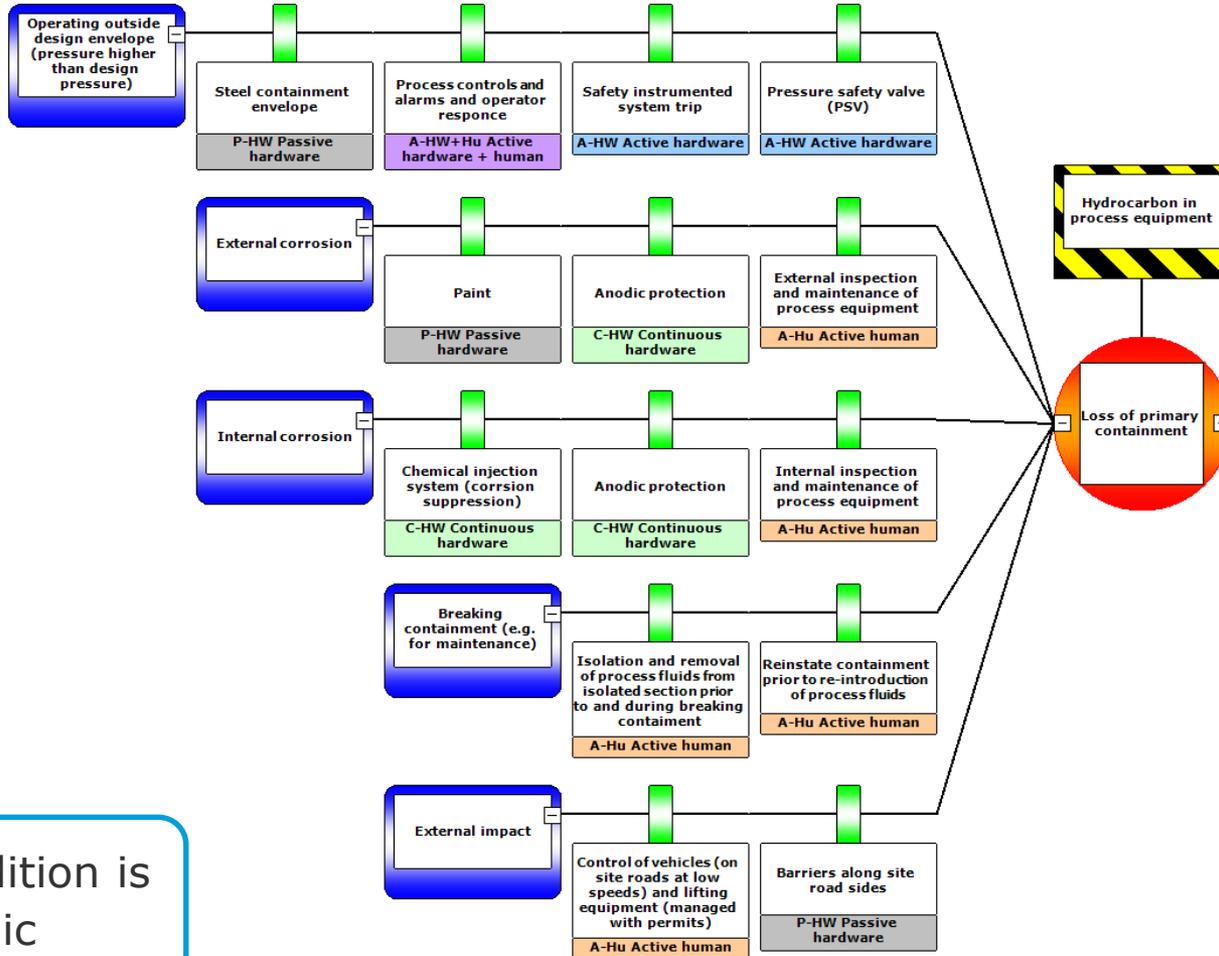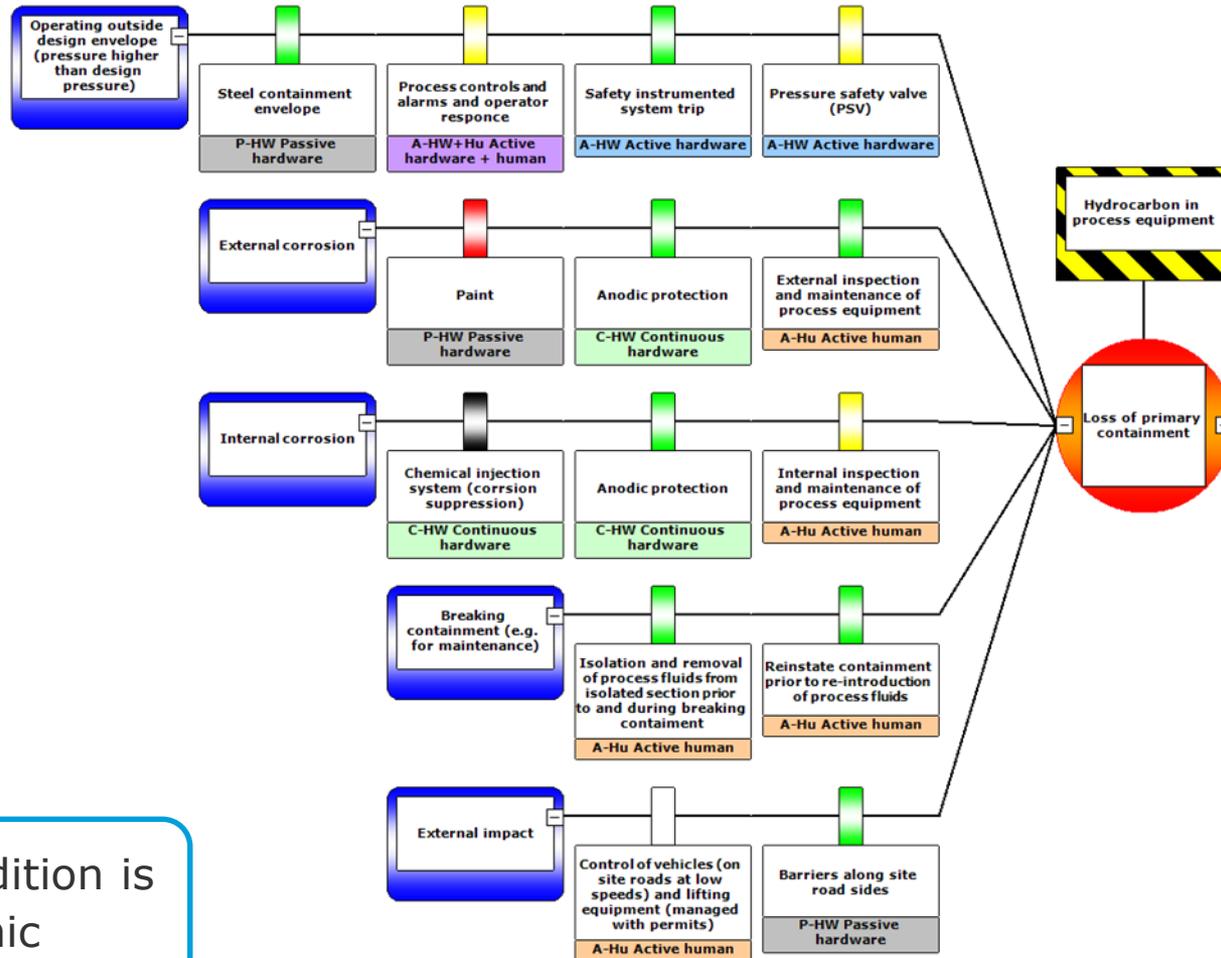
Barrier condition is dynamic

Current effectiveness (design PS effectiveness adjusted to reflect the current condition)
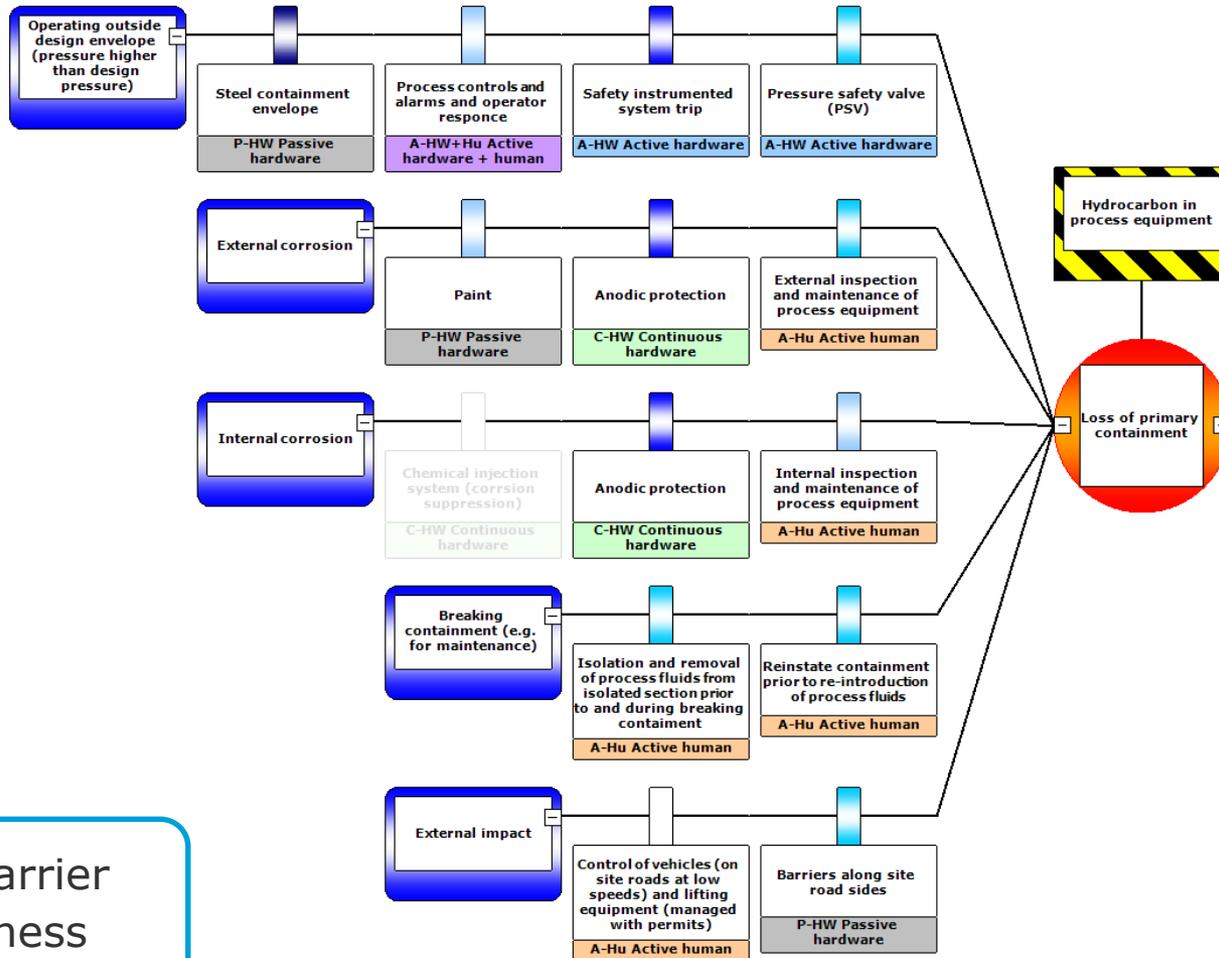

Current barrier effectiveness

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Uses of bow ties

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Uses of bow ties

- Allow the communication of accident scenarios and the understanding of the importance of barriers and degradation controls

- Uses of bow ties discussed includes:

  – Linking bow ties to the risk management system (e.g. development and verification of design and as part of risk management in operations)

  – Communicating accident scenarios and all important barriers and degradation controls (including for different audiences)

  – Sharing barrier metadata

  – Accountability and engagement

  – Assessment of risk treatment

  – Identification of safety and environmental critical information

  – Supporting ALARP demonstration

  – Supporting organisational learning through corporate bow ties for major accidents

  – Supporting investigations

  – Real time dashboards

  – …
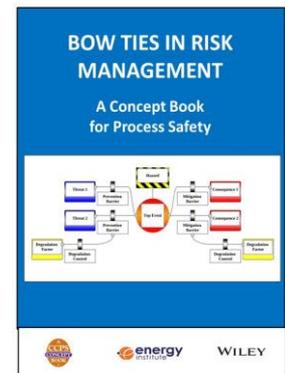
Applying the rules of the book in BowTieXP

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Setting up BowtieXP

With BowtieXP Advanced
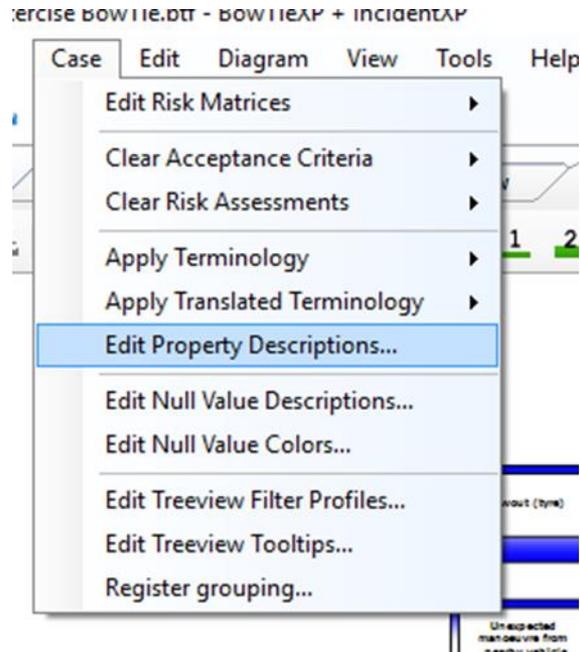
With BowtieXP Standard

- Download the CCPS template

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Setup with BowtieXP Advance

▪ Only 'element' name to change is Escalation, which is renamed to Degradation to match the guidelines/ Change columns :-

– Custom Description
– Custom plural description
– Custom abbreviation

Add the Barrier Types (in Std or Adv)

- CCPS guidance suggested the following five types
  - Passive Hardware
  - Active Hardware
  - Active Hardware + Human
 - Active Human
  - Continuous Hardware
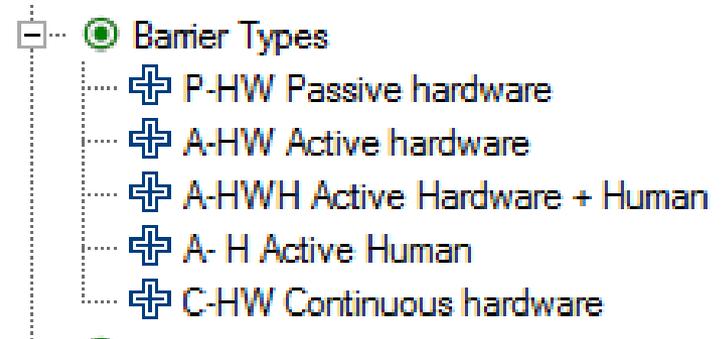
- Short titles might also be used
  - Passive
  - Active (covering Active Hardware)
  - Human (covering Active Hardware + Human and Active Human)
  - Continuous Hardware (special category not frequently used)

Add the Effectiveness (in Std or Adv)

- CCPS guidance suggested the following types

Effectiveness name	Effectiveness (design or current – must define which)
A	Barrier to prevent event or prevent or mitigate the consequence >99.9% (on demand / in operation)
B	Barrier to prevent event or prevent or mitigate the consequence >99% on demand (on demand / in operation)
C	Barrier to prevent event or prevent or mitigate the consequence >90% on demand
D	Barrier to prevent event or prevent or mitigate the consequence <90% on demand
Unknown	Unknown
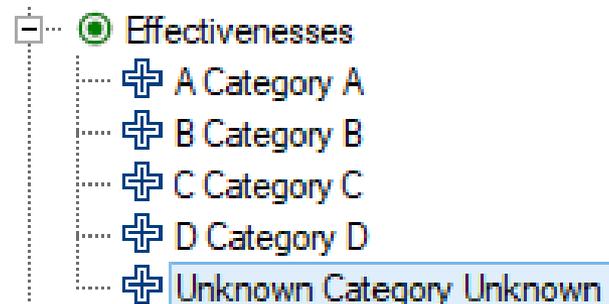
Add the Condition (in Std (BRF Code) or Adv)

- CCPS guidance suggested the following five types

Condition name	Condition description
Good / excellent	Condition assessed to be such that the barrier is performing at / above it's design (PS) effectiveness
Slightly degraded	Condition assessed to be such that the barrier is performing slightly below design (PS) effectiveness
Moderately degraded	Condition assessed to be such that the barrier is performing well below design (PS) effectiveness
Out of service (significantly degraded)	Condition assessment finds the barrier is not in place, turned-off, deactivated or fully degraded
No data	Unknown

Conditions
- GE Good / Excellent
- SD Slightly degraded
- MD Moderately degraded
- OoS Out of service
- ND No Data
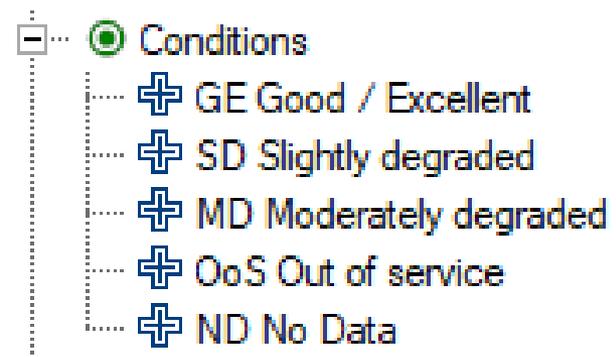
New book: Bow Ties in Risk Management

In collaboration with the Energy Institute

Also in collaboration

Centre

European Commission Joint Research

- Major Accident Hazards Bureau

Project Team Chair: Kiran Krishna, Shell
Co-Chair: Mark Scanlon, Energy Institute
Vice-Chair: Tim McGrath, Genentech (ex Chevron)
CCPS Staff Consultant: Charles Cowley
Principal author: Robin Pitblado, DNV GL
Sub-contractor to DNV GL: CGE Risk
(Ben Keetlaer, Paul Haydock)

Peer Review group
Some of the peer review participants, in addition to companies of the working group.

UKPIA Major Hazards Working Group
UK Health & Safety Executive (HSL)
API RP 75 revision
COMAH, Environment Agency England
Process Safety & Reliability Group
ExxonMobil
Patrick Hudson Independent Consultant ex Professor, Delft University
John Sherban, Systematic Risk Mgt.

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Keith Serre	Nexen
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Danny White	BHP Billiton

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Peter Jeffries	Phillips66
Rob Miles	Hu-Tech
Rob Saunders	Shell
Donald Smith	ENI

Project Team members: EC JRC MAHB
Zsuzsanna Gyenes	EC JRC MAHB
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Introduction to the CCPS / Energy Institute Process Safety book:

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Presentation by Mark Boult and Paul McCulloch

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