



# Runway Incursion Safety Assessment

Facilitator: Eng. Herbert Wedel MsC

# Concept of safety

## ❖ Is safety?

- Zero accidents or serious incidents (*a view widely held by the travelling public*)
- Freedom from hazards (*i.e. those factors which cause or are likely to cause harm*)
- Attitudes towards unsafe acts and conditions by employees of aviation organizations
- Error avoidance
- Regulatory compliance
- ... ?

# Concept of safety

## ❖ **Consider** (*the weaknesses in the notion of perfection*)

- Total elimination of accidents (and serious incidents) is unachievable
- Failures will occur, despite the most accomplished prevention efforts
- No human activity or human-made system can be guaranteed to be absolutely free from hazard and operational errors
- **BUT controlled** safety risks and **controlled** errors are acceptable in an inherently safe system



# Concept of safety (Doc 9859)



❖ **Safety** is the state in which the possibility of harm to persons or property damage is reduced to, and maintained at or below, an acceptable level through a **continuing process** of hazard identification and safety risk management

- ❖ **Traditional approach – Preventing accidents**
  - Focus on outcomes or unsafe acts by operational personnel
  - May attach blame/punishment for failures to “perform safely”
  - Addresses identified safety concern(s) exclusively
  - Refers mainly to regulatory non-compliance
- ❖ **Identifies**

**WHAT?**

**WHO?**

**WHEN?**

- ❖ **But is not always able to determine**

**WHY?**

**HOW?**



# The concept of a consequence causation

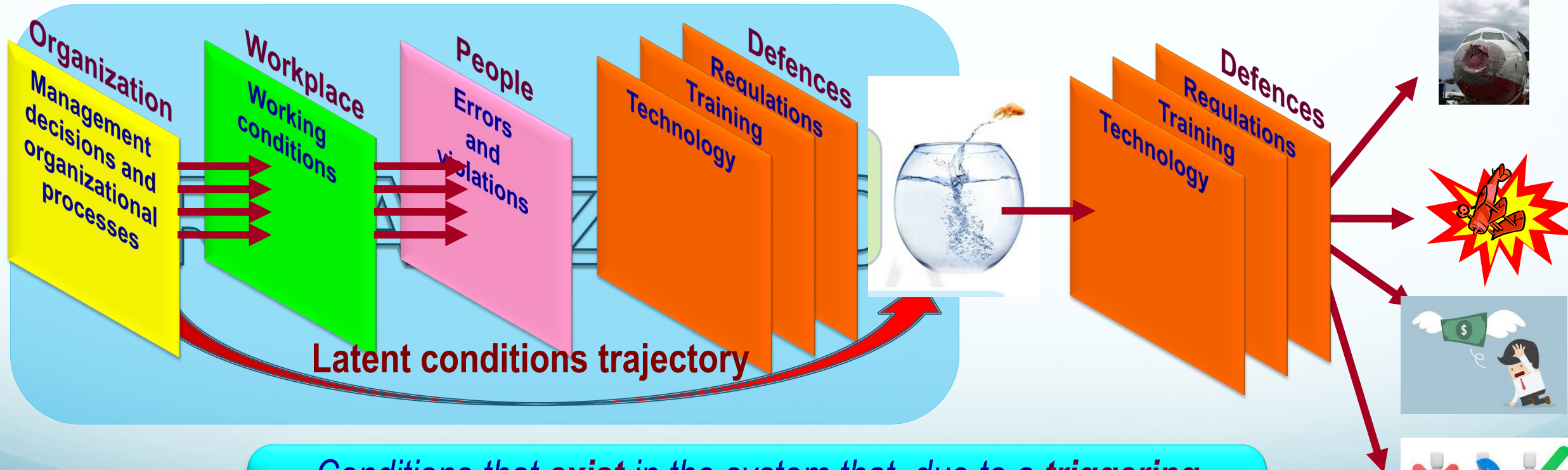
Threads

Proactive  
barriers

Undesired event

Reactive  
barriers

Consequences



Conditions that **exist** in the system that, due to a **triggering factor** and/or **sequence of events**, result in an undesirable event that could lead us to a consequence.





# Definition of safety risk

- ❖ **Safety risk** – The assessment, expressed in terms of predicted **probability** and **severity**, of the consequence(s) of a hazard taking as reference the worst foreseeable situation



# Let's learn some concepts








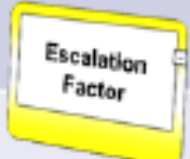
Consequence



Threat



Top  
Event

	Term	Meaning
	Hazard	Something in, around or part of the system which has the potential to cause damage
	Undesired State (Top Event)	State when control is lost over the Hazard
	Threat (Triggering Event)	Whatever will cause the Undesirable Event
	Barrier/Mitigation	Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.
	Consequence	Results from the Undesirable Event
	Escalation Factor	Factors or conditions which make a barrier/mitigation to fail

## ■ Hazard Identification



### Hazard

**A condition or an object with the potential to cause or contribute to an aircraft incident or accident**

- A hazard is:
  - An activity or state, which, in case of **failure**, can lead to **negative outcomes**
  - A **normal and identifiable** system component (part of normal business), whose **consequences are usually manageable**





## ▪ Hazard Identification

### ▪ Guidelines :

- Hazards are part of normal business
- Hazards exist, they do not 'happen'
- Describe and define the hazard carefully



### ▪ Hazards Formulation:






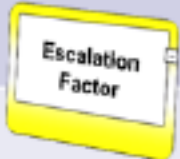
- Describe the hazard in the desired (controlled) state.
- Use commonly accepted names
- Provide situational context
- Give an indication of scale



- Hazard Identification

- Exercise: Every row contains a hazard that is not accurately described according to the previous criteria. Try to pick the odd one out!

<b>Uncontrolled Fire</b>	<b>Birds around aerodrome</b>	<b>Aircraft in flight</b>
<b>Air transport of people</b>	<b>Aircraft in motion</b>	<b>Landing gear not deployed</b>
<b>Jet fuel spill</b>	<b>Air turbulence</b>	<b>Landing aircraft</b>

	Term	Meaning
	Hazard	Something in, around or part of the system which
	Undesired State (Top Event)	State when control is lost over the Hazard
	Threat (Triggering Event)	Whatever will cause the Undesirable Event
	Barrier/Mitigation	Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.
	Consequence	Results from the Undesirable Event
	Escalation Factor	Factors or conditions which make a barrier/mitigation to fail



- Top Event



Top  
Event

**STATE WHEN CONTROL IS LOST  
OVER THE HAZARD**



- Also known as Undesired State or Unsafe Event:
  - The **first event** in a chain of negative events **leading to unwanted consequences**
  - It is not a catastrophe yet, but now there is exposition to the potential harm of the hazard.
  - However, it should be possible to bring the situation under control again.

## Bow Tie Step by Step

### ■ Top Event

#### ■ Guidelines :

- Top events are not disasters (disasters are often consequences)
- Hazards can have multiple top events
- Usually involves a change of 'state'
- Describe how control is lost
- Give an indication of scale if possible

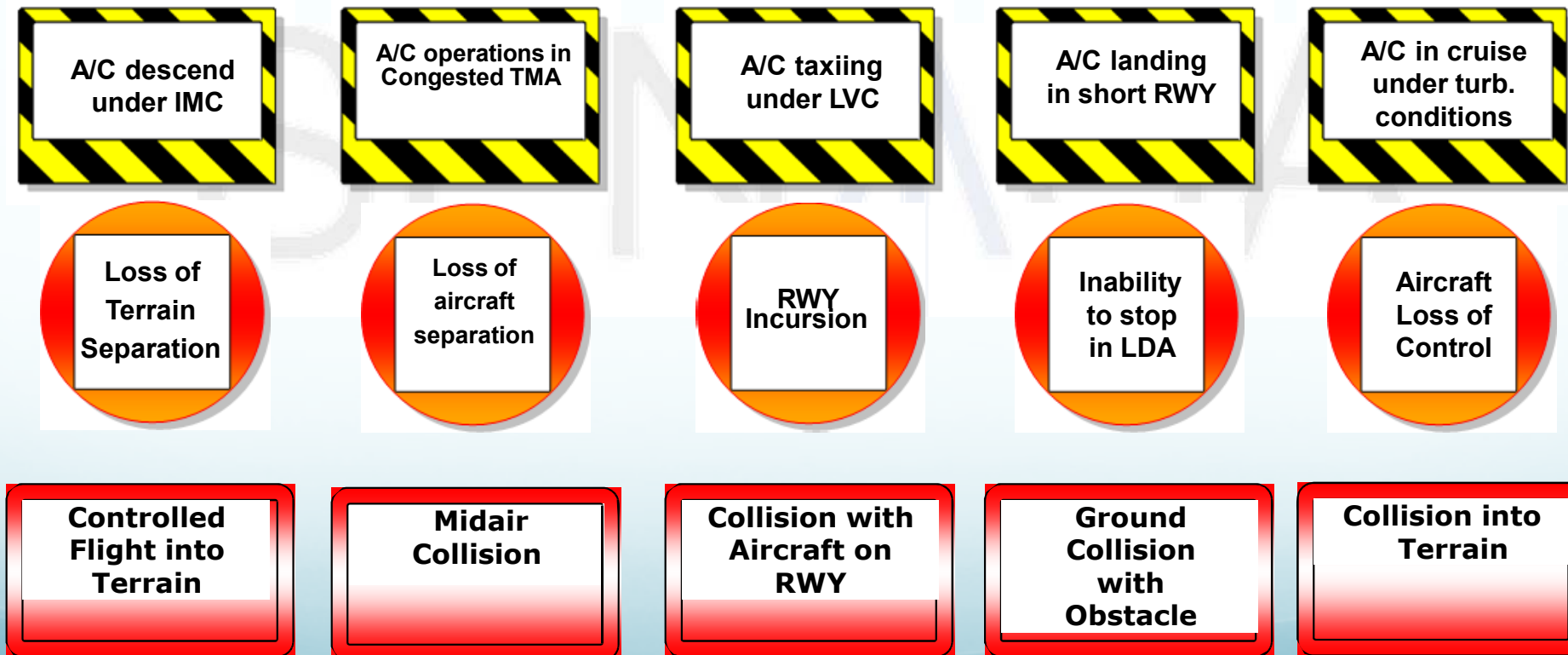


#### ■ Formulation:

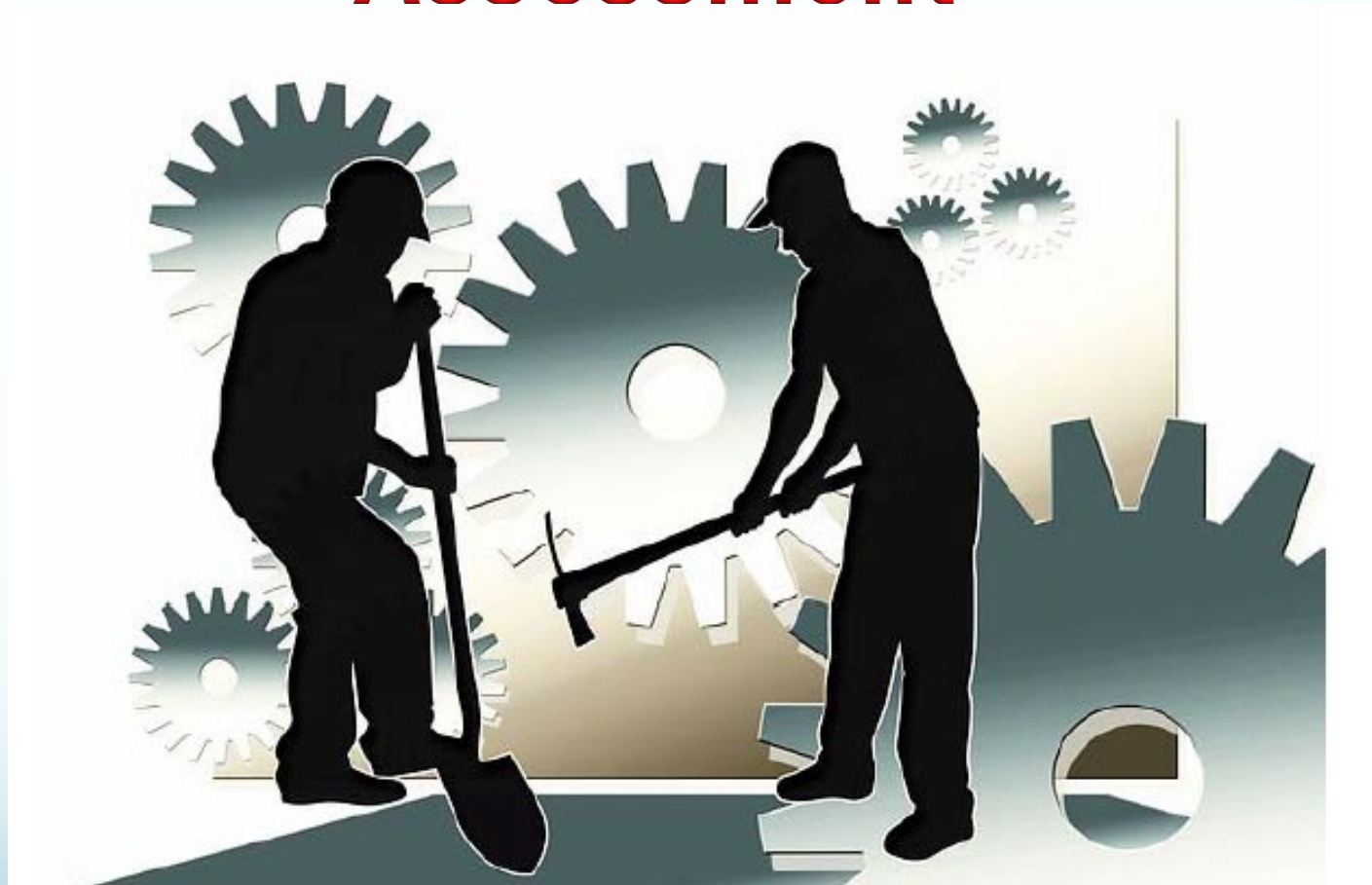
- It can be helpful to use disasters to come up with the right top events: to think about the first event that initiated the final phase of this disaster
- Start with 'Loss of control' and refine it later on, once the context has become clearer
- Check if the consequences of a top event can still be mitigated. If not, the chosen top event might actually be a consequence of another top event that needs to be identified

# Top Event

- Exercise: Define Top Events for the following combinations of Hazards and Consequences

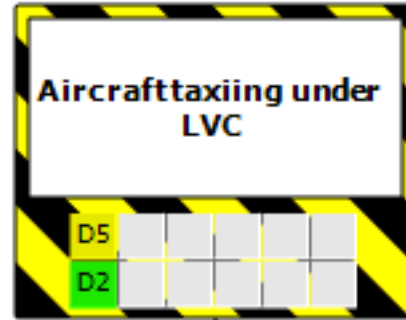


# Let's See: Runway Incursion Safety Assessment

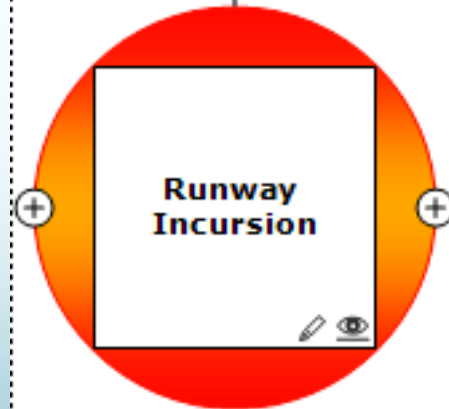









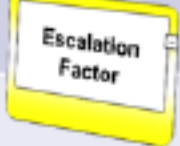
HAZARD



UNDESIRABLE EVENT  
(TOP EVENT)



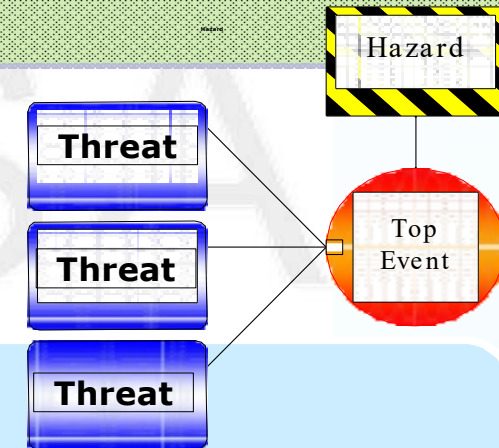


Term		Meaning
	Hazard	Something in, around or part of the system which has the potential to cause damage
	Undesired State	State when control is lost over the Hazard
	Threat (Triggering Event)	Whatever will cause the Undesirable Event
	Barrier/Mitigation	Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.
	Consequence	Results from the Undesirable Event
	Escalation Factor	Factors or conditions which make a barrier/mitigation to fail





• A possible cause that can release the Hazard by producing the Top Event



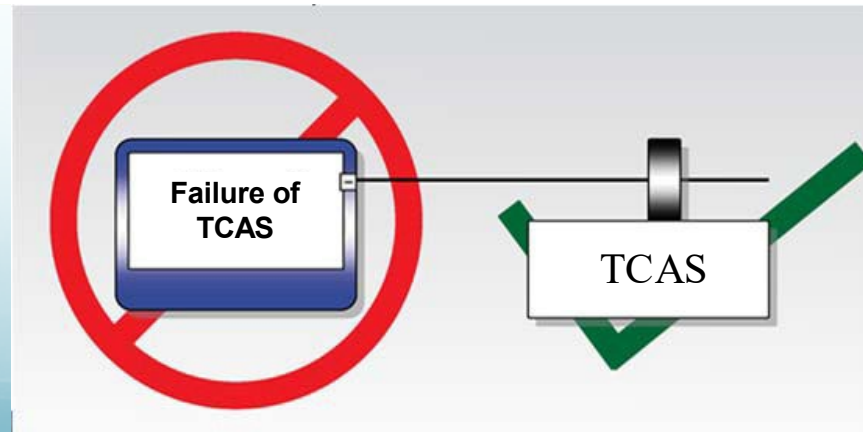
- Also known as Causes or Triggering Event:
  - There can be **multiple threats** for one top event
  - Each threat represents a **single scenario** that could directly and independently **lead to the top event**.
  - Direct means **causally direct** (not necessarily in terms of time)

# Take into account this rules!!

## ■ Threats

### ■ **No Barrier Failures:**

- The failure of a barrier is never the primary cause of an incident, because the barrier always tries to prevent a force from harming the system
- A threat should be a force or condition that pushes an unwanted chain of events further. A primary process failure will do that. For instance an engine failure can lead to a loss of control of an aircraft.
- A barrier failure is the absence of a good thing. It doesn't push the unwanted chain of events forwards, but it just sits by and does nothing, while a threat leads to a top event



## ■ Threats

### ■ Guidelines :

- Threats should be direct
- Each threat should be sufficient and independent
- Barrier failures are not threats

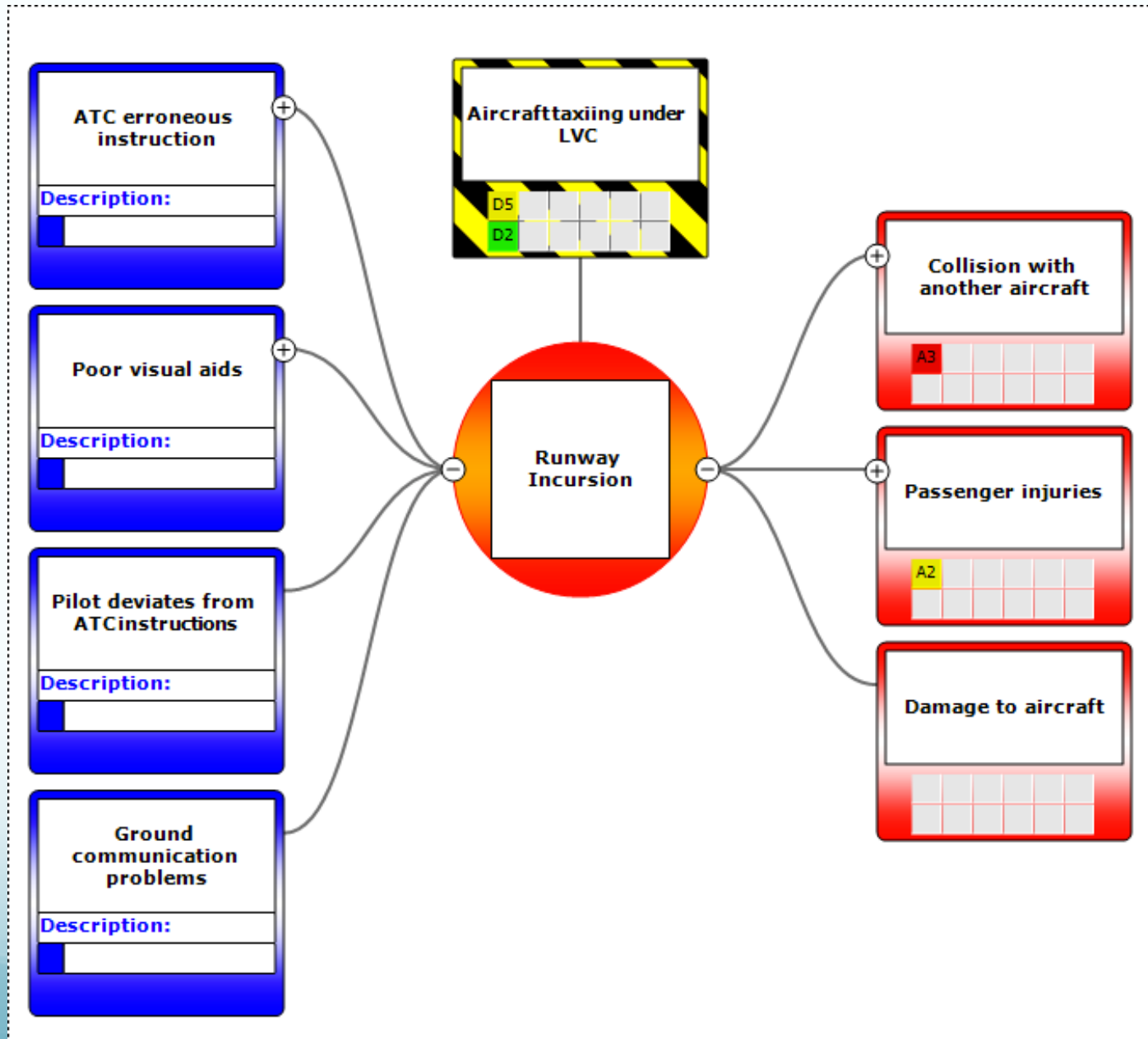
Exercise: Is it a Threat or not? Why?

No pre-flight briefing	Pilot incapacitated	Strong winds	Inspection not done
Pilot Error	GPWS Failure	Intoxicated Crew	Incompetent personnel
Contaminated RWY	Engine failure	Fuel shortage	Aircraft Diversion






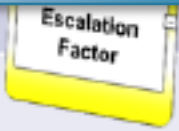
# Runway Incursion Safety Assessment



THREATS



CONSEQUENCES

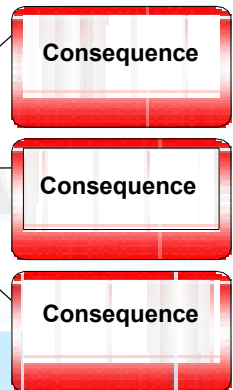
	Term	Meaning
	Hazard	Something in, around or part of the system which has the potential to cause damage
	Undesired State (Top Event)	State when control is lost over the Hazard
	Threat (Triggering Event)	Whatever will cause the Undesirable Event
	Barrier/Mitigation	Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.
	Consequence	Results from the Undesirable Event
	Escalation Factor	Factors or conditions which make a barrier/mitigation to fail



## Consequences

Consequence

• An unwanted event resulting from the release of the Hazard



### Also known as Potential Outcomes

- Consequences are events that are caused by the top event
- What we ultimately want to prevent



## ■ Consequences

### ■ Guidelines :

- Consequences are events
- Not the actual loss or damage (yet)
- Consequences can be formulated in terms of ADREP categories

Exercise: Correct Consequence?

Controlled flight  
into terrain

Collapsed  
landing gear

Evacuation





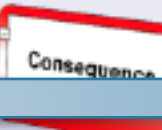
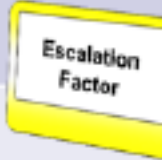
Environmental  
damage

Runway  
excursion

Injury

Emergency  
landing

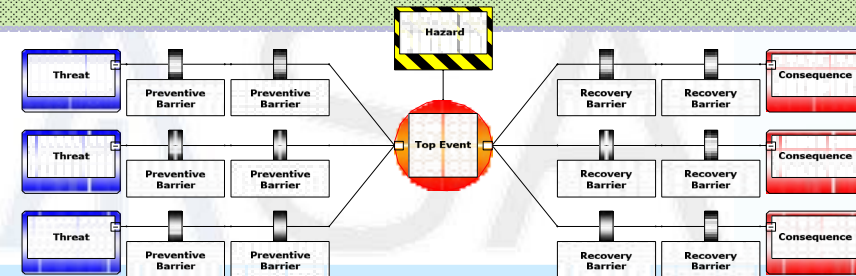
Mid-air collision

Term		Meaning
	Hazard	Something in, around or part of the system which has the potential to cause damage
	Undesired State (Top Event)	State when control is lost over the Hazard
	Threat (Triggering Event)	Whatever will cause the Undesirable Event
	Barrier/Mitigation	Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.
	Consequence	Results from the Undesirable Event
	Escalation Factor	Factors or conditions which make a barrier/mitigation to fail

## ■ Barriers



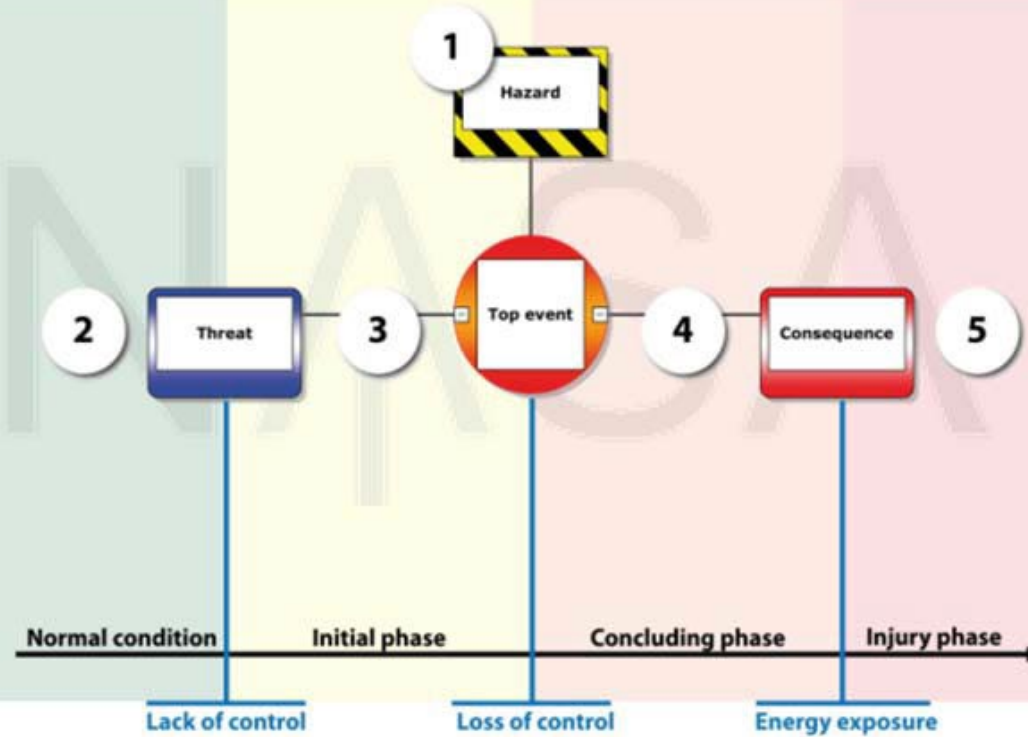
- Safety barriers are physical and/or non-physical means planned to prevent, control, or mitigate undesired events or accidents



- Also known as controls or mitigations. there are three different places for barriers :
  - Between a threat and the top event (preventive barriers – also known as proactive barriers)
  - Between the top event and a consequence (recovery barriers, also known as reactive or defense barriers)
  - Between a barrier and an escalation factor (escalation factor barriers)

## Barrier Function

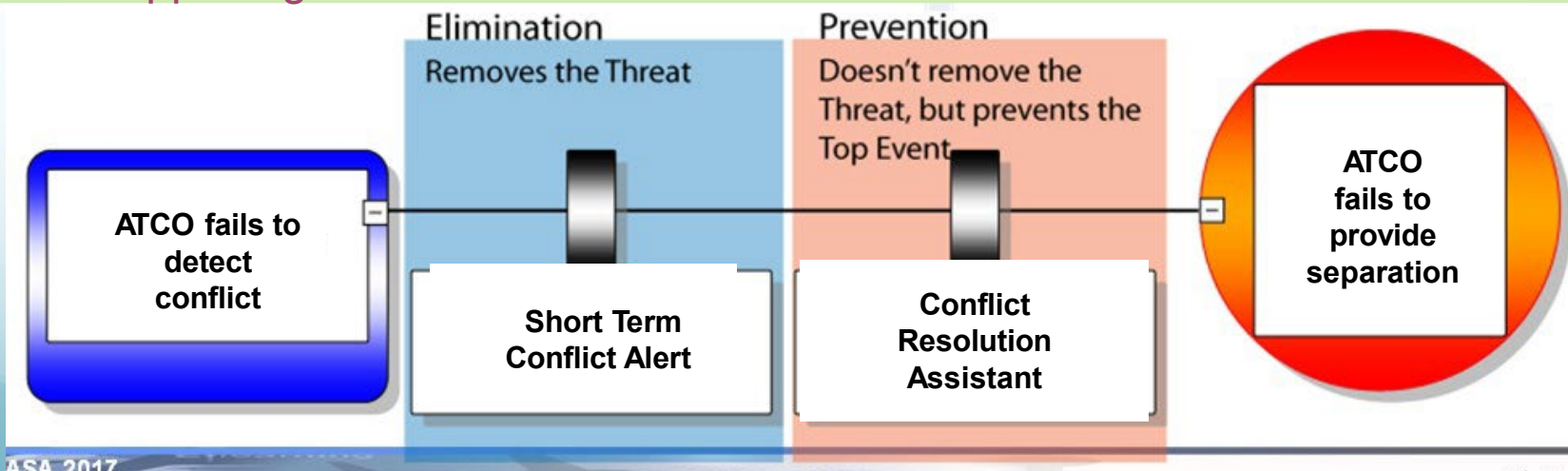
1. **Eliminate / Substitute** Hazard
2. **Eliminate** Threat
3. **Prevent** Top event
4. **Separate** Consequence
5. **Mitigate** Consequence



## ■ Barriers

### ■ Preventive Barriers:

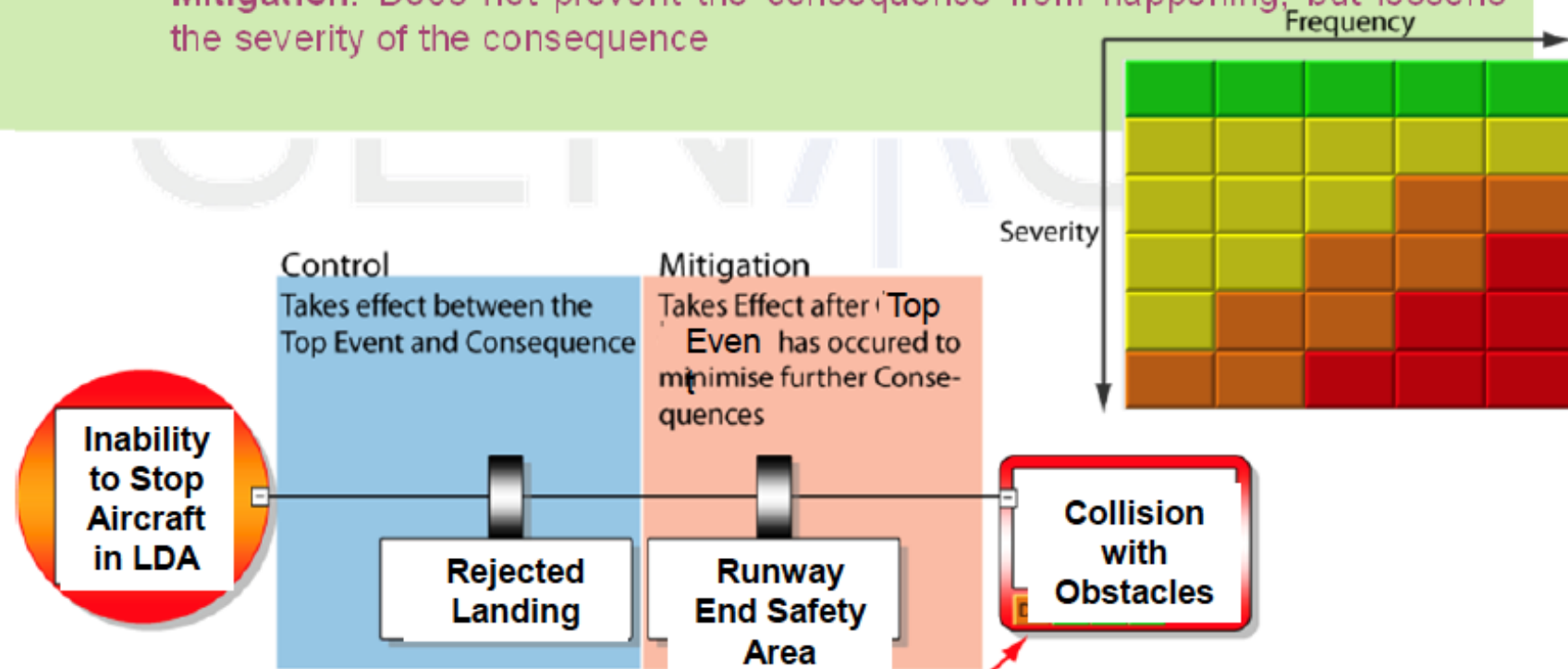
- Act against a threat/top event. Its effect takes place before the top event has happened (always present on the left side of the bowtie diagram). It can follow two strategies:
  - **Elimination.** Remove the threat and make sure that there is nothing (or less) to cause the top event (they should appear to the left of the threat, but for simplicity purposes they are located to the right)
  - **Prevention.** stop the threat from becoming a top event, either by blocking the causal effect of the threat or directly stopping the top event from happening





## Recovery Barriers:

- Aimed at regaining control once it is lost (Top Event has occurred). They act on the likelihood or severity of a potential consequence through:
  - Control.** Prevents the consequence from happening
  - Mitigation.** Does not prevent the consequence from happening, but lessens the severity of the consequence

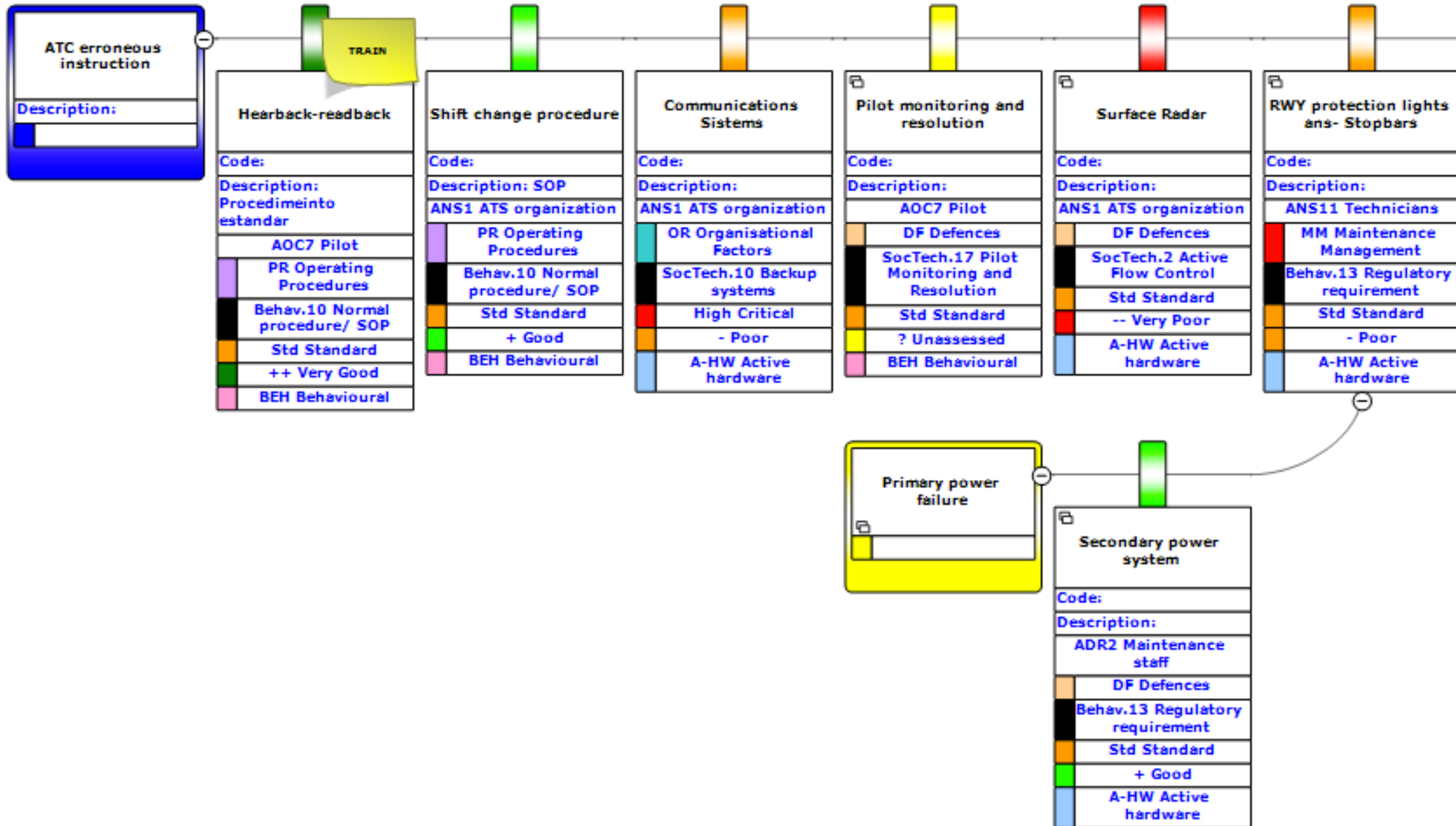







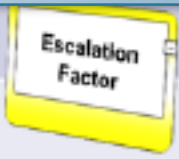


## ■ Barriers

- Guidelines :
  - Preventive Barriers (Proactive)
    - The focus is on eliminating the threat
    - Then prevent or reduce the top event
    - Effect delivered before the top event
  - Recovery Barriers (Reactive)
    - No effect upon the top event – has already happened
    - Works on likelihood and severity
    - Effect delivered after the top event
    - Effect (possibly) also delivered after the consequence
  - Focus on the barriers that are implemented and can be controlled by the organization
  - Consider splitting (or not) barrier with specific consequences/threats if necessary

# Let's See: Runway Incursion Safety Assessment



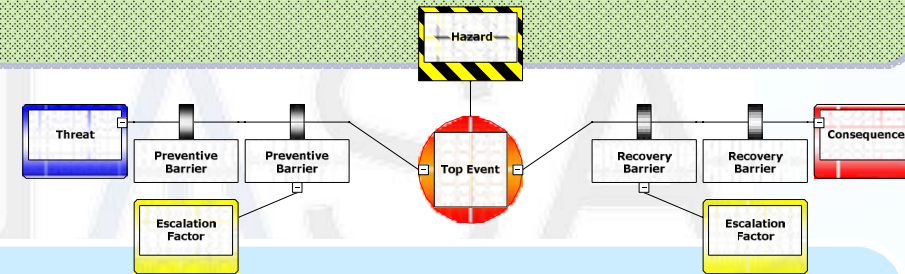
Term		Meaning
	Hazard	Something in, around or part of the system which has the potential to cause damage
	Undesired State (Top Event)	State when control is lost over the Hazard
	Threat (Triggering Event)	Whatever will cause the Undesirable Event
	Barrier/Mitigation	Elements that interrupt the propagation so that the triggering event does not result in a Loss of Control of the Hazard or do not escalate into a potential outcome.
	Consequence	Results from the Undesirable Event
	Escalation Factor	Factors or conditions which make a barrier/mitigation to fail

## Bow Tie Step by Step

### Escalation Factors

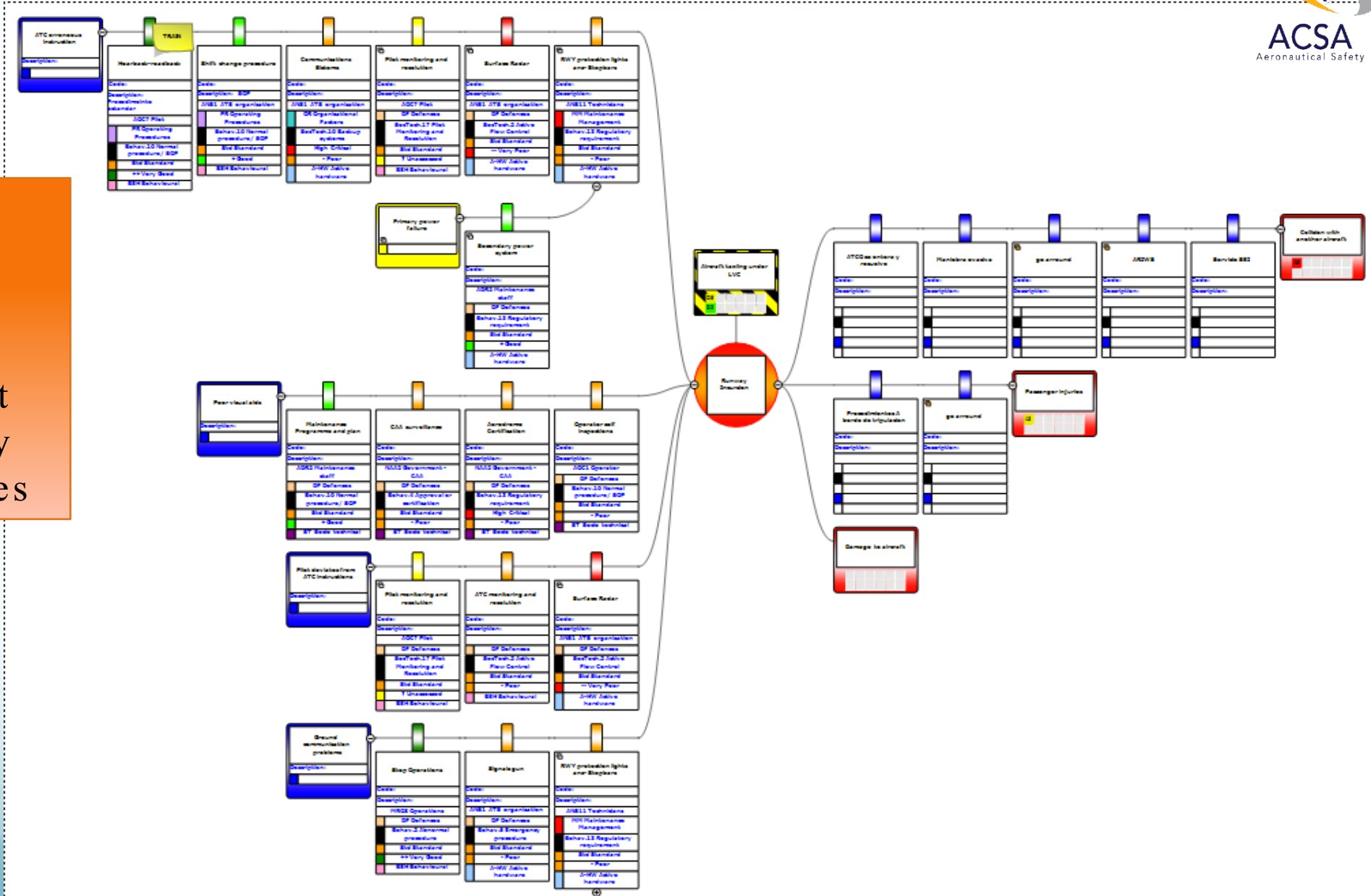
#### Escalation Factor

- a condition that leads to increased risk by defeating or reducing the effectiveness of a Barrier



- An escalation factor cannot directly cause an event but increases the chance that a certain threat or top event will, by taking out a barrier
- the following three escalation factor categories can be used :
  - Human factors:** anything a person does to make a barrier less effective
  - Abnormal conditions:** anything in the environment that causes a barrier to be put under strain
  - Loss of critical services:** if a barrier relies on an outside service, losing that service might cause it to lose effectiveness

# Let's See: Runway Incursion Safety Assessment



For any of the threats, if the barriers are ineffective, we will reach the Top Event and once there, any of the consequences are possible.

For any of the threats, if the barriers are ineffective, we will reach the Top Event and once there, any of the consequences are possible.





**RISK**

**ASSESSMENT**

# Introduction

## ▪ Risk Management Review



### Hazard Identification

- When and Where



### Hazard Analysis

- Causes, Consequences & Barriers



### Hazard Probability

- Risk analysis: Probability

Probabilidad de eventos		
Definición	Explicación	Nivel
Alto	Probabilidad que ocurre a diario o con frecuencia	3
Medio	Probable que ocurra alguna vez en la vida profesional	4
Bajo	Probable que ocurra alguna vez en la vida profesional	5
Muy bajo	Muy improbable que ocurra (una vez en la vida profesional)	2
Extremadamente bajo	Extremadamente improbable que ocurra (una vez en la vida profesional)	1



### Hazard Consequences

- Risk analysis: Severity

Severidad de eventos		
Definición	Explicación	Nivel
Alto	Lesiones graves o muerte	5
Medio	Lesiones moderadas o graves	4
Bajo	Lesiones leves o moderadas	3
Muy bajo	Lesiones leves o moderadas	2
Extremadamente bajo	Lesiones leves o moderadas	1



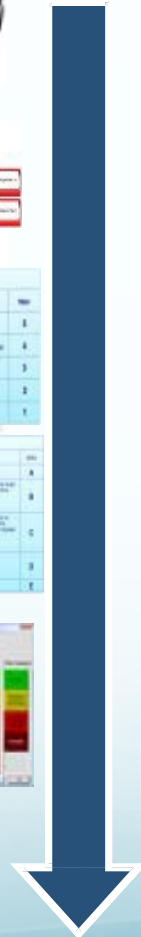
### Hazard Tolerability

- Risk analysis: Evaluation



### Actions to take

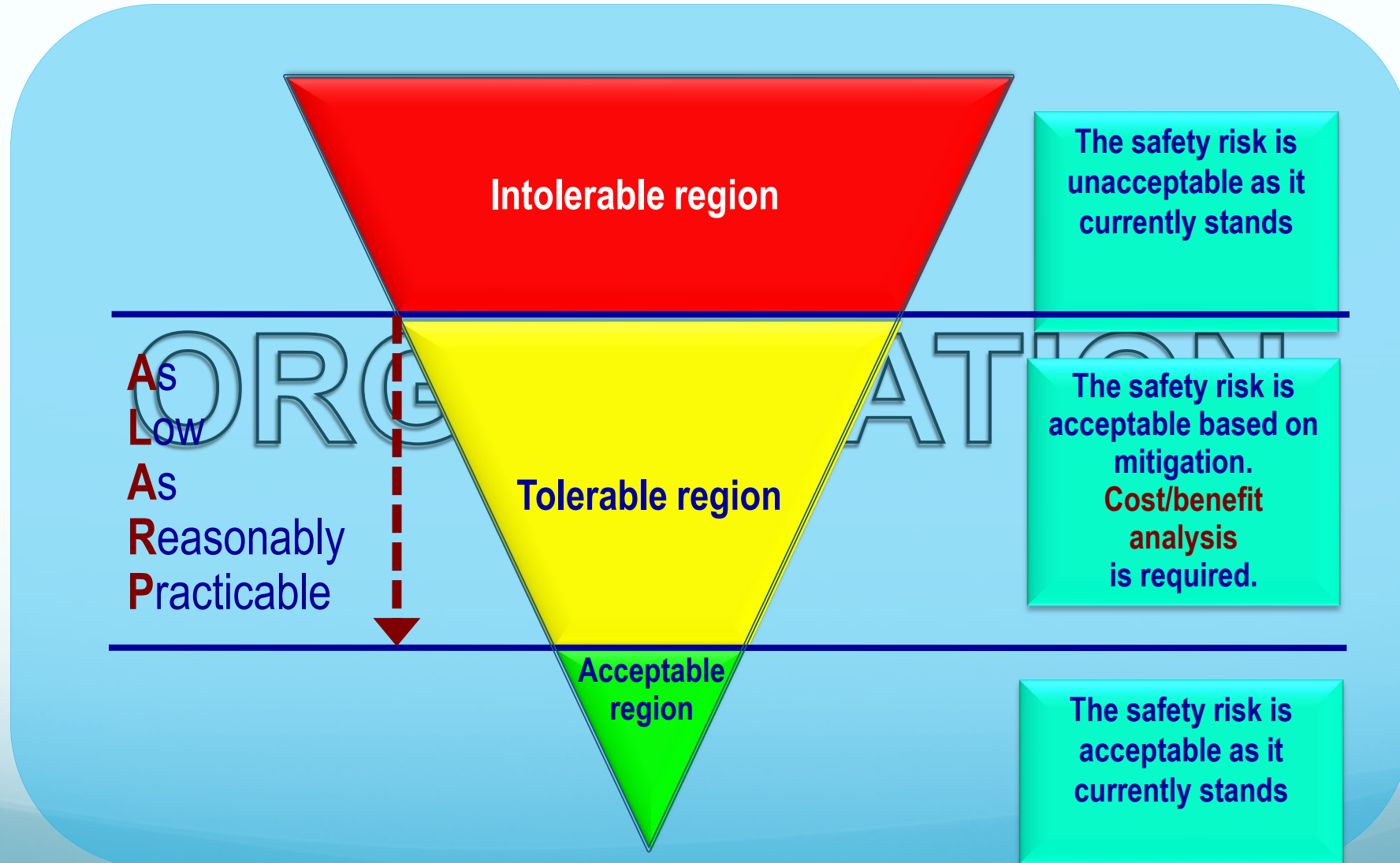
- Risk control: Mitigation



# Definition of safety risk

- ❖ **Safety risk** – The assessment, expressed in terms of predicted **probability** and **severity**, of the consequence(s) of a hazard taking as reference the worst foreseeable situation
  - *A wind of 15 knots blowing directly across the runway is a **Threat***
  - *A pilot may not be able to control the aircraft during takeoff or landing is a **top event** of the hazard*
  - *The assessment (quantification) of the **consequences** of the potential loss of control of the aircraft by the pilot, expressed in terms of probability and severity, is the **safety risk***

# Safety Risk Assessment



# Cost-benefit analysis

## ❖ Direct costs

- The obvious costs, which are easily determined. The high costs of exposure to hazards can be reduced by insurance coverage
  - ✓ purchasing insurance only transfers monetary risk, it **does not address the safety hazard**

## ❖ Indirect costs

- The uninsured costs. An understanding of uninsured costs (or indirect costs) is fundamental to understand the economics of safety



❖ Indirect costs may amount to more than the direct costs resulting from exposure to hazards

- Loss of business
- Damage to the reputation
- Loss of use of equipment
- Loss of staff productivity
- Legal actions and claims
- Fines and citations
- Insurance deductibles



# Cost-benefit analysis

❖ Indirect costs may amount to more than the direct costs resulting from exposure to hazards

- Loss of business
- Damage to the reputation
- Loss of use of equipment
- Loss of staff productivity
- Legal actions and claims
- Fines and citations
- Insurance deductibles

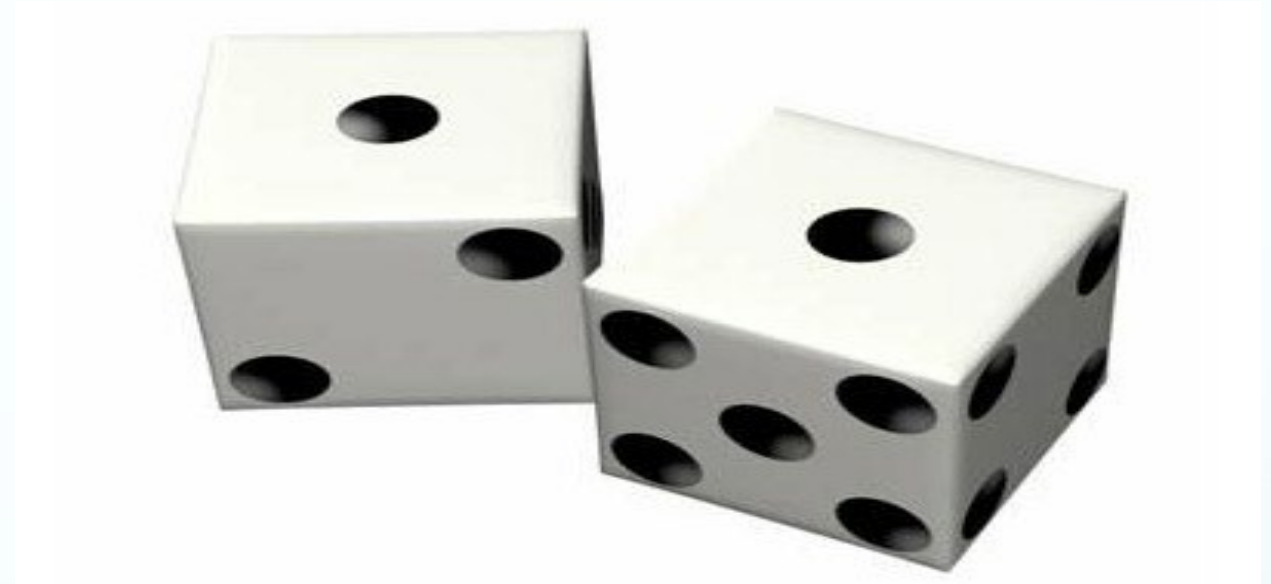


## ❖ Definition

➤ Probability – The likelihood that an unsafe event or condition might occur

• ... questions such as

- what number of operating or maintenance personnel must follow the procedure(s) in question?
- how frequently is the equipment or procedure under assessment used?



# Third fundamental – Safety risk severity



- Definition
  - Severity – The possible effects of an unsafe event or condition, taking as reference the worst foreseeable consequence

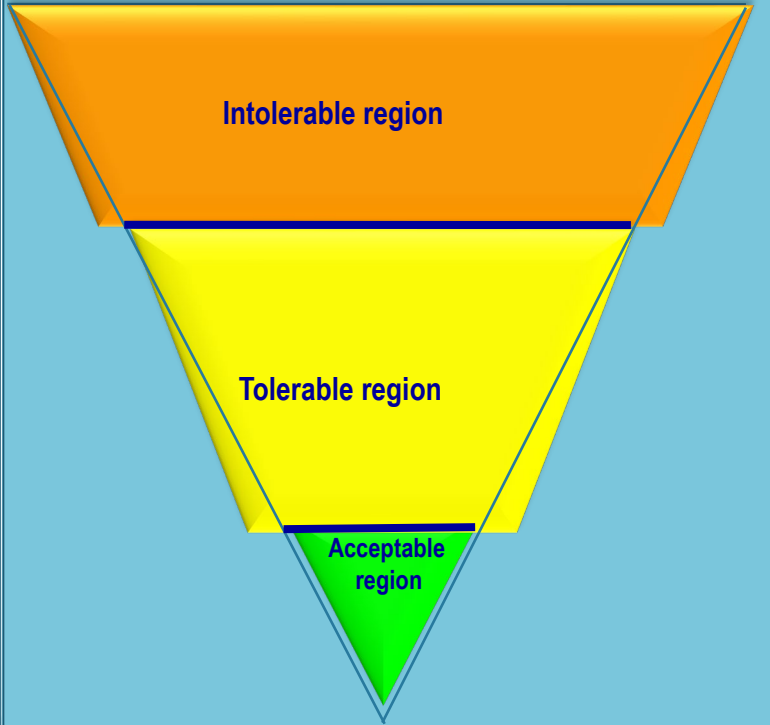
# Third fundamental – Safety risk severity

Severity of occurrences		
Aviation definition	Meaning	Value
<b>Catastrophic</b>	<ul style="list-style-type: none"> <li>➤ Equipment destroyed.</li> <li>➤ Multiple deaths.</li> </ul>	<b>A</b>
<b>Hazardous</b>	<ul style="list-style-type: none"> <li>➤ A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely.</li> <li>➤ Serious injury.</li> <li>➤ Major equipment damage.</li> </ul>	<b>B</b>
<b>Major</b>	<ul style="list-style-type: none"> <li>➤ A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency.</li> <li>➤ Serious incident.</li> <li>➤ Injury to persons.</li> </ul>	<b>C</b>
<b>Minor</b>	<ul style="list-style-type: none"> <li>➤ Nuisance.</li> <li>➤ Operating limitations.</li> <li>➤ Use of emergency procedures.</li> <li>➤ Minor incident.</li> </ul>	<b>D</b>
<b>Negligible</b>	<ul style="list-style-type: none"> <li>➤ Little consequences</li> </ul>	<b>E</b>

# Fourth fundamental – Safety risk index/ tolerability

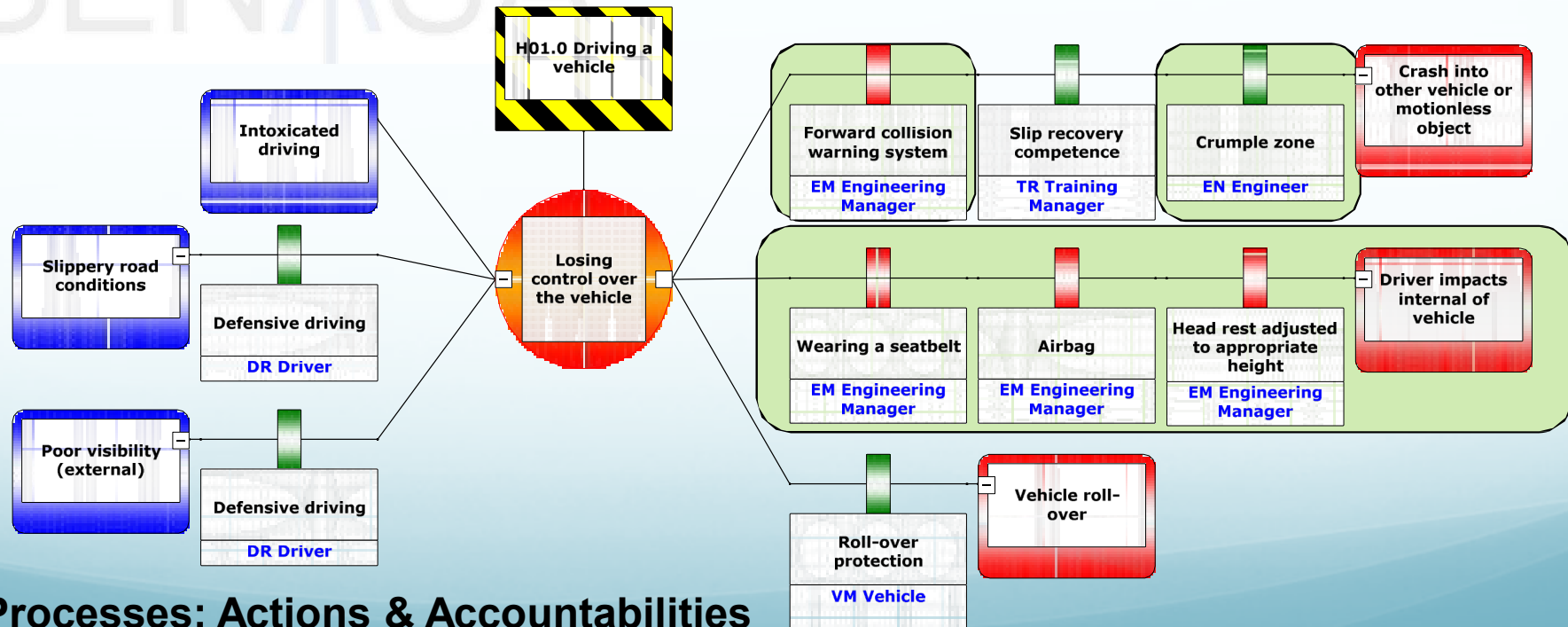
Safety risk probability		Safety risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E



Safety risk management	Assessment safety risk index	Suggested criteria
	<p><b>5A, 5B, 5C, 4A, 4B, 3A</b></p>	<p>Unacceptable under the existing circumstances</p>
	<p><b>5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C</b></p>	<p>Acceptable based on safety risk mitigation. It might require management decision.</p>
	<p><b>3E, 2D, 2E, 1A, 1B, 1C, 1D, 1E</b></p>	<p>Acceptable</p>

# Applications

HAZARD	SAFETY EVENTS (CAUSES)	CONSEQUENCE	MITIGATIONS (BARRIERS)	RISK	ADDITIONAL MITIGATIONS	RESIDUAL RISK	ACTIONS
Driving a car / Losing control over the car	Intoxicated driving Slippery road conditions Poor visibility	Crash into other car or fixed object  Driver impacts internal of a car  Vehicle roll-over	Airbag Defensive drive Head rest adjustment Seatbelt Forward collision warning system Rollover protection Crumple zone design				Vehicle Manager Engineering Manager Training Manager Driver



SMS Processes: Actions & Accountabilities

## Fifth fundamental – Safety risk control/ mitigation

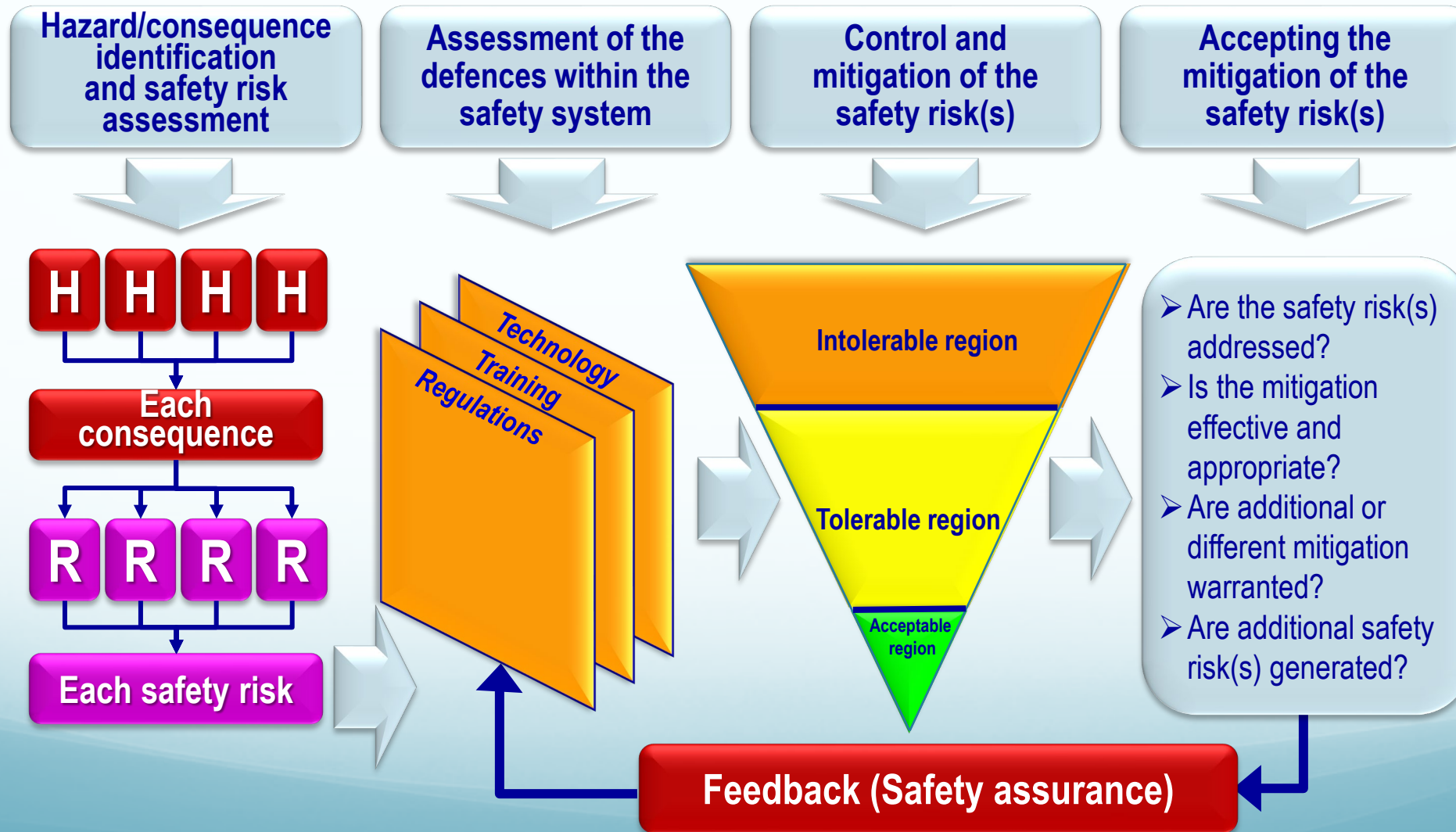
- Definition
  - **Mitigation** – Measures to address the potential hazard or to reduce the safety risk probability or severity of the consequence(s) of the hazard
    - Safety risk mitigation = Safety risk control

# Fifth fundamental – Safety risk control/ mitigation

- Strategies

- **Avoidance** – The operation or activity is cancelled because assessed safety risks exceed the benefits of continuing the operation or activity
  - Operations at an aerodrome surrounded by complex geography and without the necessary aids are cancelled
- **Reduction** – The operation or activity is subject to limitations, or action is taken to reduce the severity of the consequence(s) of the hazard(s)
  - Operations at an aerodrome surrounded by complex geography and without the necessary aids are limited to day-time, visual conditions
- **Segregation of exposure** – Action is taken to isolate the effects of the consequence(s) of the hazard(s) or build in redundancy to protect against it
  - Operations at an aerodrome surrounded by complex geography are limited to aircraft with specific performance navigation capabilities

# Safety risk mitigation at a glance







Thank you, have a safe day