HOW TO RISK ASSESS

USING THE NEW ARMS METHODOLOGY
AND ADVANTAGES COMPARED TO OLDER METHODS

BY THE ARMS WORKING GROUP

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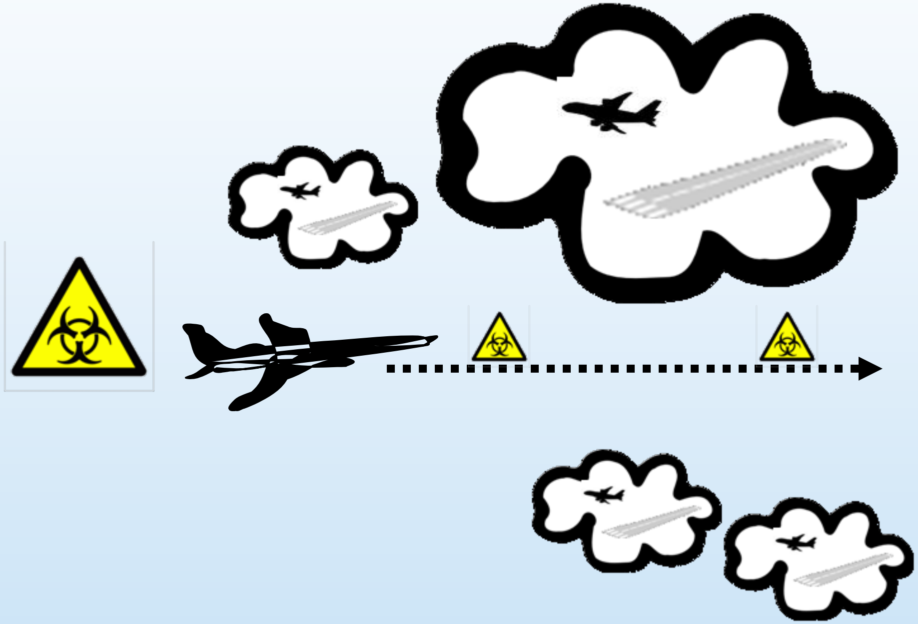
PART ONE

BASIC FRAMEWORK FOR RISK ASSESSMENT

The ARMS way of thinking

- An aircraft is in operation, in the presence of Hazard(s)
  - Hazard is a condition or an object with the potential of causing injuries to personnel, damage to equipment or structures, loss of material, or reduction of ability to perform a prescribed function. (ICAO)

The ARMS way of thinking

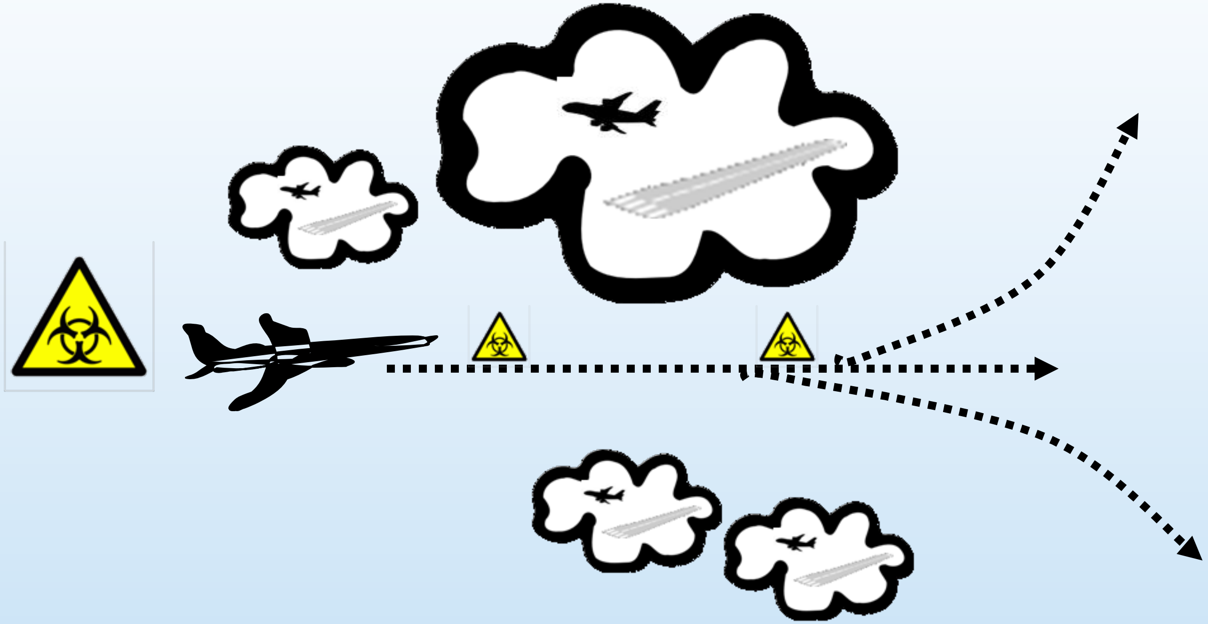


- There is also always a specific *<u>context</u>*:
  - Aircraft type
  - Condition of aircraft
  - Passenger load
  - Weather conditions
  - Airport conditions:
    - Runway length and condition
    - Obstructions
    - Crash zone
  - Fitness and fatigue level of people involved
  - Etc.

- These *contextual factors* will influence both the probabilities and severity levels of various scenarios/outcomes.

The ARMS way of thinking

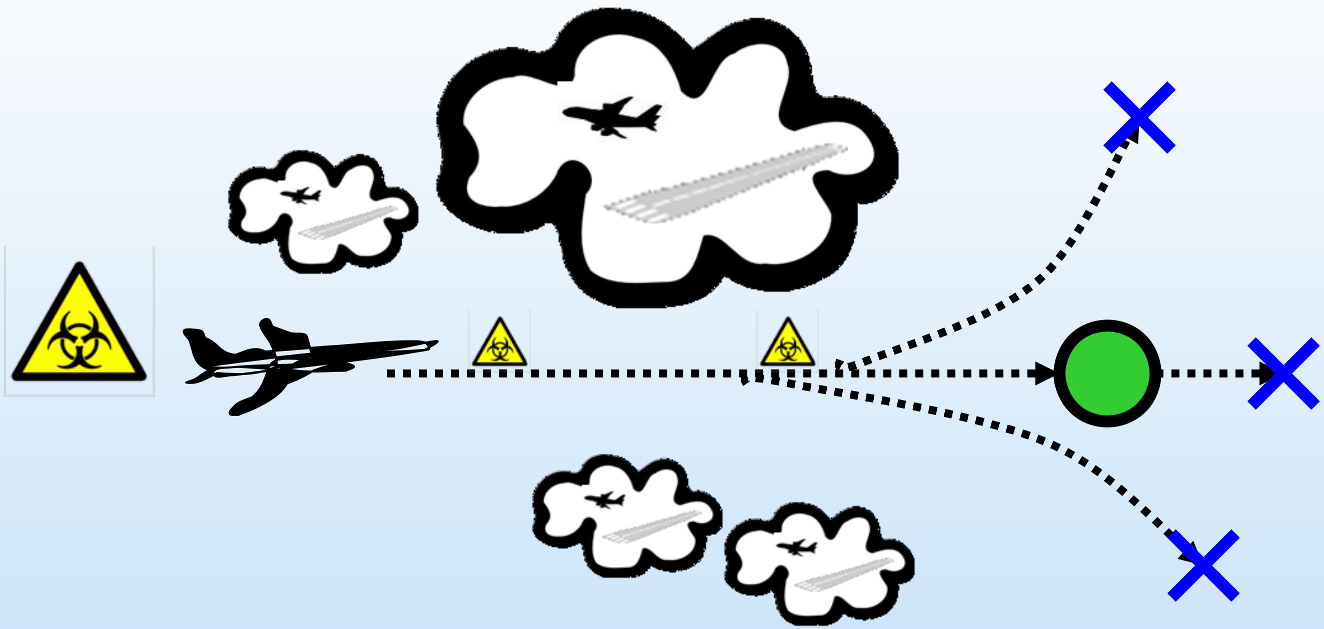
- The sequence could develop in various ways



- In other words, for on-going or future sequences, there are several *potential outcomes*.

The ARMS way of thinking

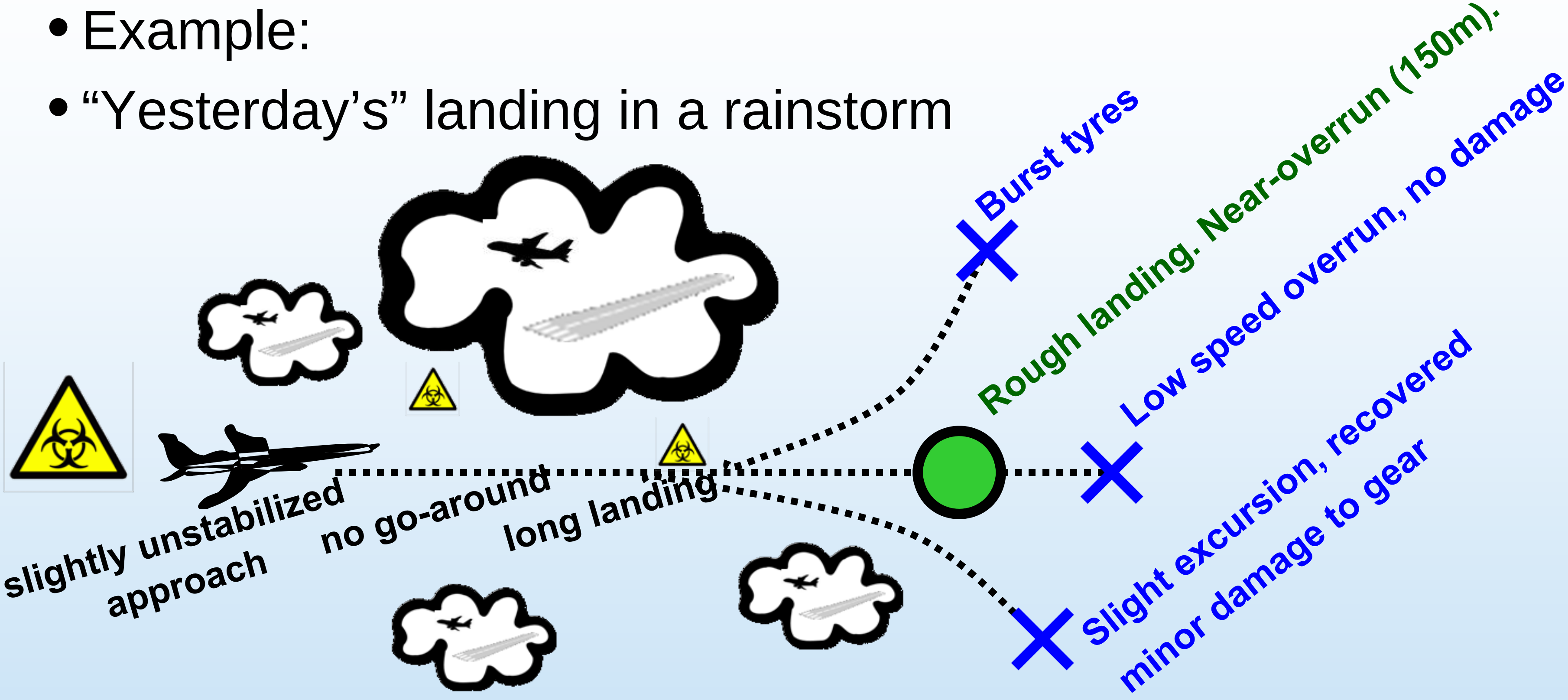
- Once the sequence is history, there is a factual, real-life outcome. This is called the *actual outcome* (green ball).



- The sequence *could have* led to other imaginable outcomes, *potential outcomes* (blue crosses).
  - These potential outcomes would have varying levels of severity (loss, damage, cost, etc.)

The ARMS way of thinking

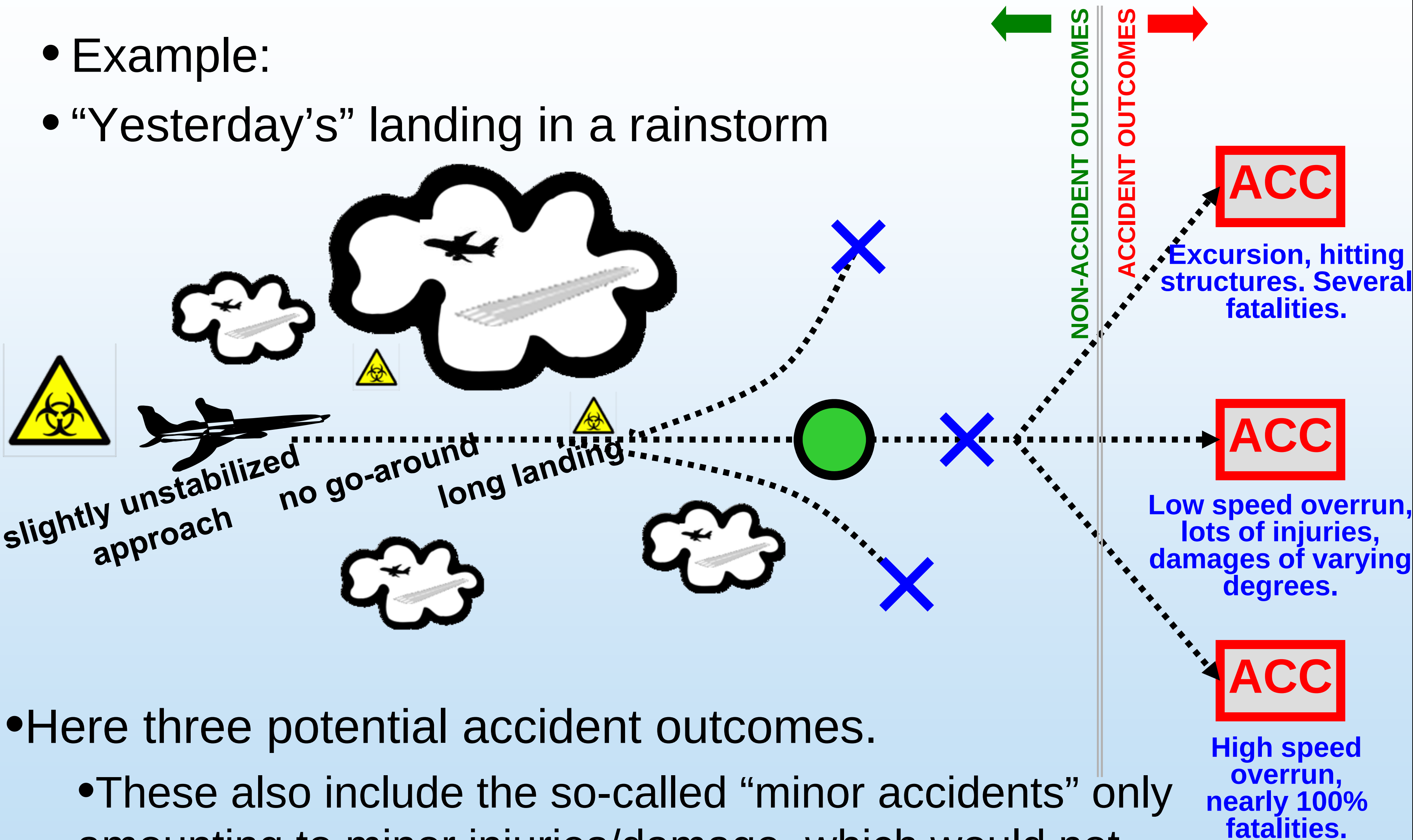
- Example:
- “Yesterday’s” landing in a rainstorm



- These potential outcomes are not yet accidents
- What we are really interested in, are the (potential) <u>accident</u> outcomes (because we do not want them to happen).

The ARMS way of thinking

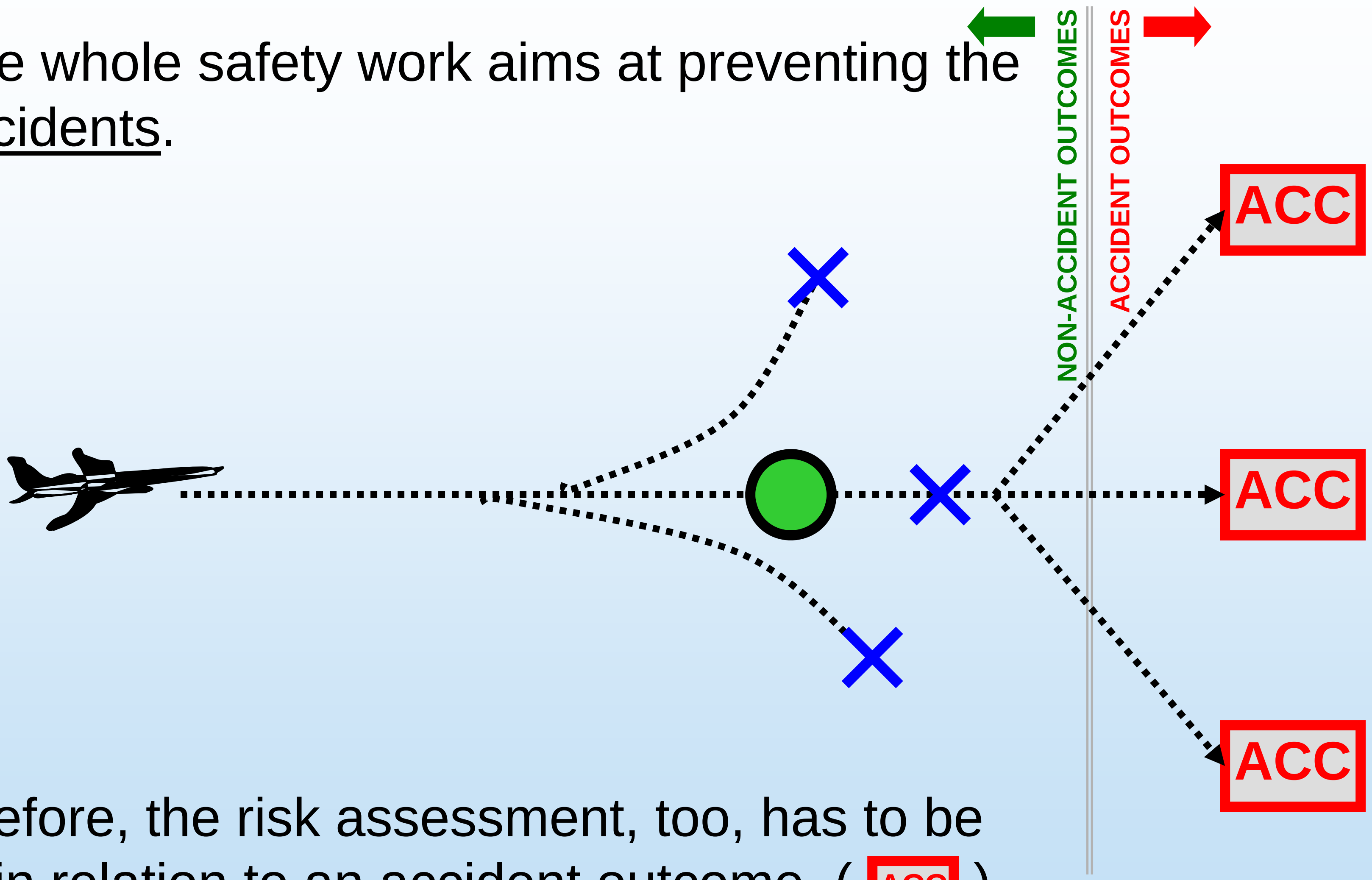
- Example:
- "Yesterday's" landing in a rainstorm



- Here three potential accident outcomes.
  - These also include the so-called "minor accidents" only amounting to minor injuries/damage, which would not necessarily be accidents as per the ICAO definition

The ARMS way of thinking

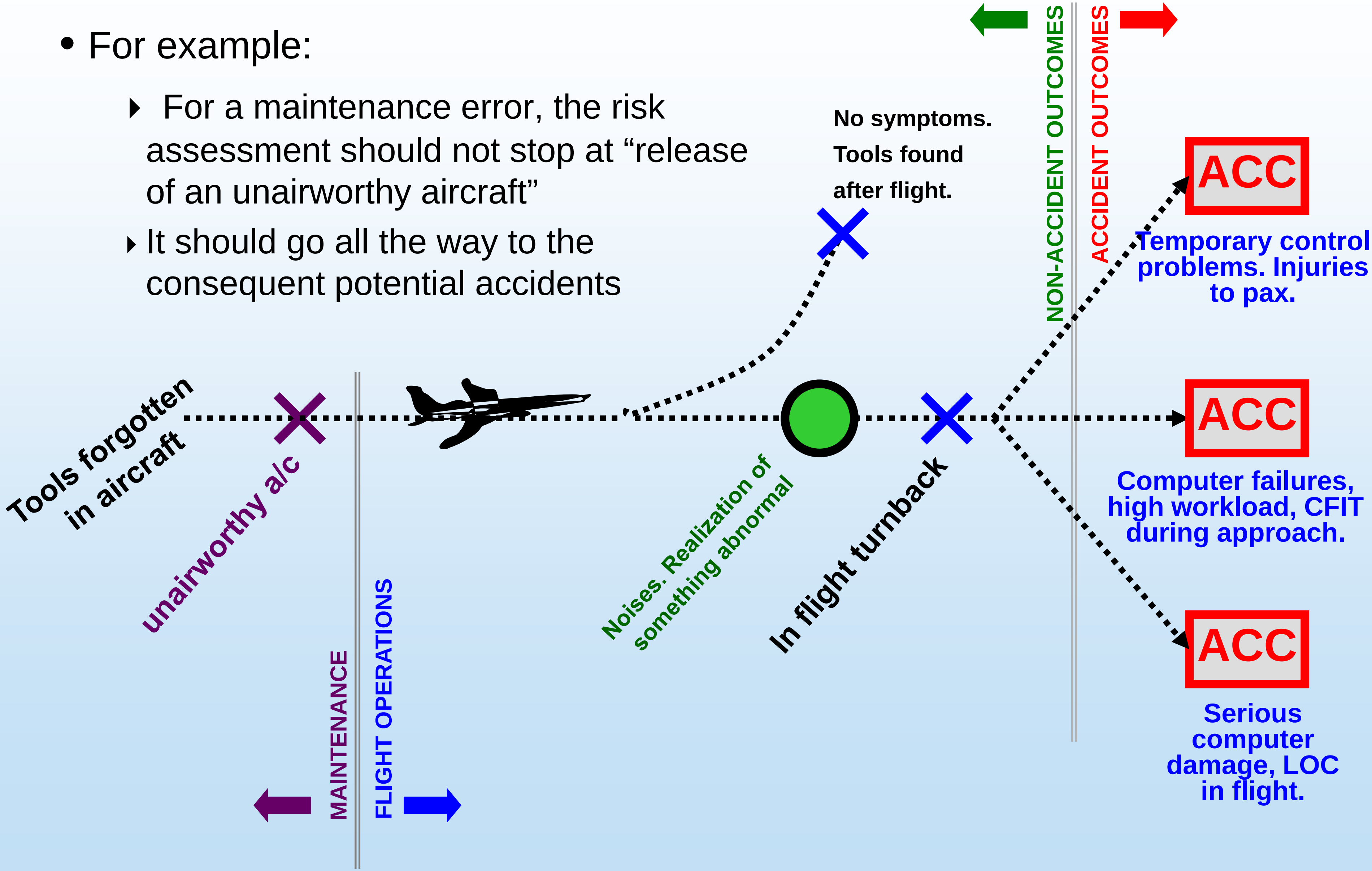
- The whole safety work aims at preventing the <u>accidents</u>.



- Therefore, the risk assessment, too, has to be done in relation to an accident outcome. (ACC)
  - A common mistake is to limit the assessment to an intermediate outcome (✕)

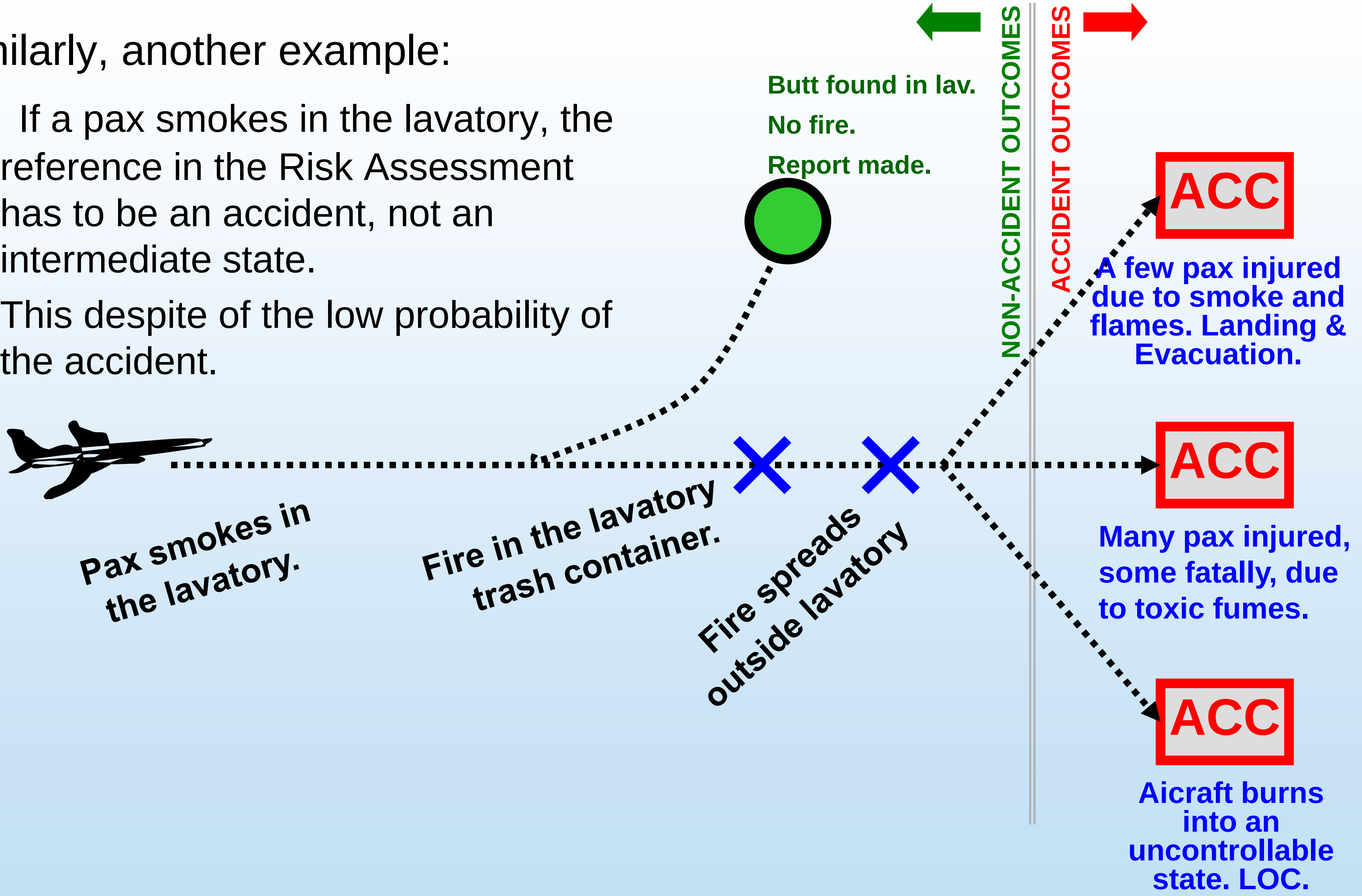
The ARMS way of thinking

- For example:
  - For a maintenance error, the risk assessment should not stop at "release of an unairworthy aircraft"
  - It should go all the way to the consequent potential accidents



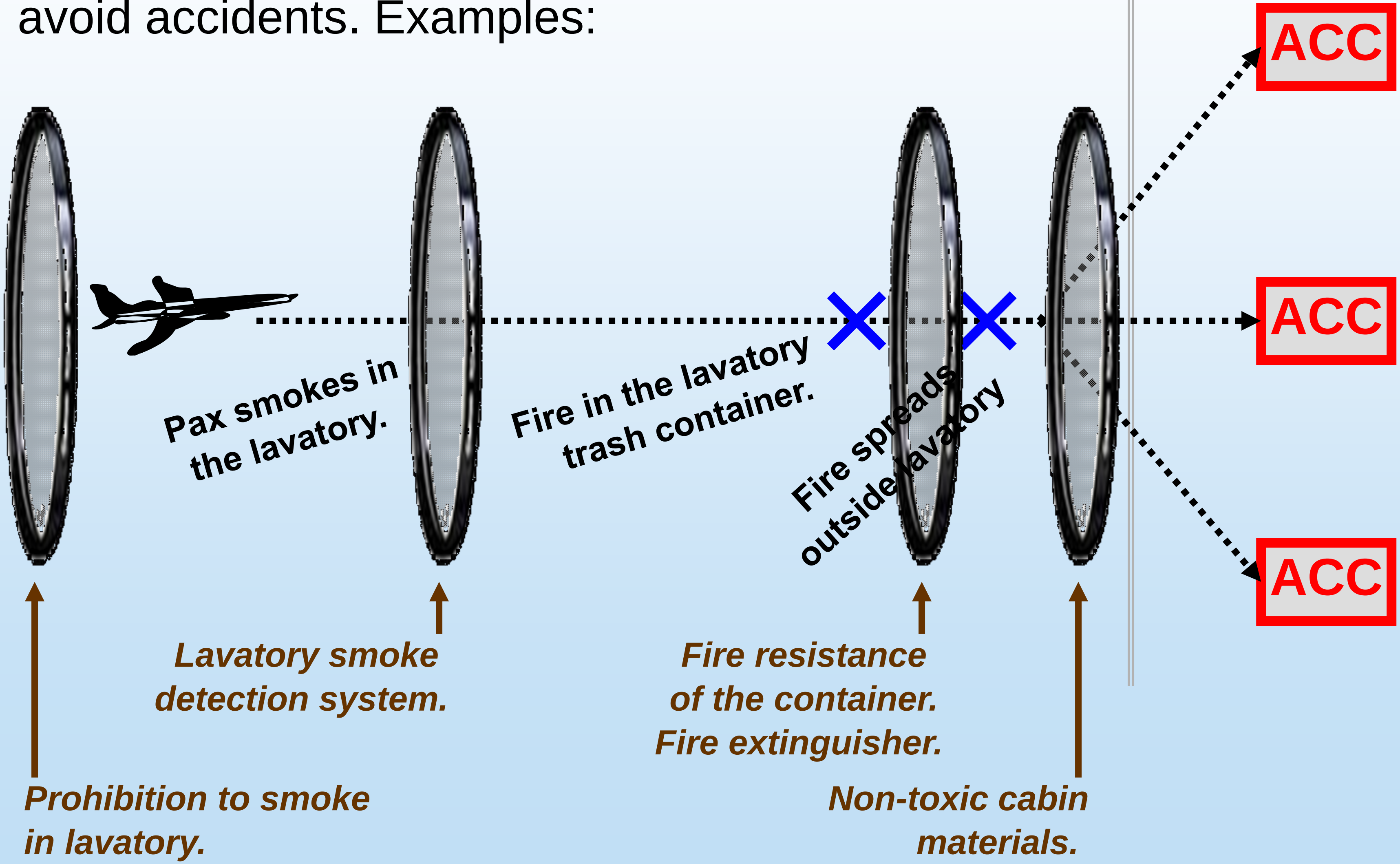
The ARMS way of thinking

- Similarly, another example:
  - If a pax smokes in the lavatory, the reference in the Risk Assessment has to be an accident, not an intermediate state.
  - This despite of the low probability of the accident.



The ARMS way of thinking

- The aviation system contains a lot of ***barriers*** (i.e. ‘Risk Controls’) in order to avoid accidents. Examples:



The ARMS way of thinking

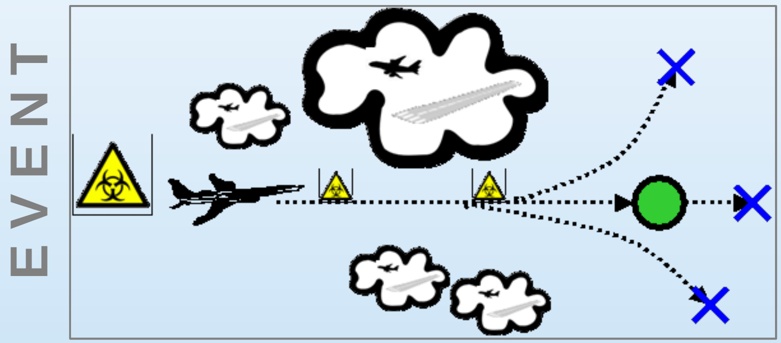
- Some barriers work by trying to *Prevent* an undesirable operational state (i.e. a situation which could developed into an accident)
  - e.g. Windshear detection systems try to prevent the plane from getting into windshear
- Some barriers work by trying to *Recover* the system into a safe state.
  - e.g. TCAS warns about a potential mid-air collision risk, thereby allowing the crew(s) to recover the situation
- Barriers can also be called Risk Controls. ICAO definition:
  - *Measures to address the potential hazard or to reduce the risk probability or severity* (ICAO)
- The barriers are an important element in the Risk Assessment

PART TWO

RISK ASSESSMENT USING ARMS

What is risk assessed?

- The first fundamental question to answer is: what should be risk assessed, individual safety *Events* or larger *Safety Issues*?
  - Events are historical facts. Like discussed above, every event takes place in a specific context. There is an *actual outcome* (fact). Alternative *potential outcomes* can be imagined.



  - Safety Issue does not equal to one factual event. It is a defined (safety) problem (*issue*) believed to affect the operational system. The full definition follows on next slide.

Safety Issue defined

- A manifestation of a hazard or combination of several hazards in a specific context.
- The Safety Issue has been identified through the systematic Hazard Identification process of the organization.
- Usually the Safety Issue is highlighted through recurrence of similar events, but sometimes one single potentially severe event may lead to raising the Safety Issue
- The Safety Issue could be a local implication of one hazard (e.g. de-icing problems in one particular aircraft type) or a combination of hazards in one part of the operation (e.g. operation to a demanding airport).

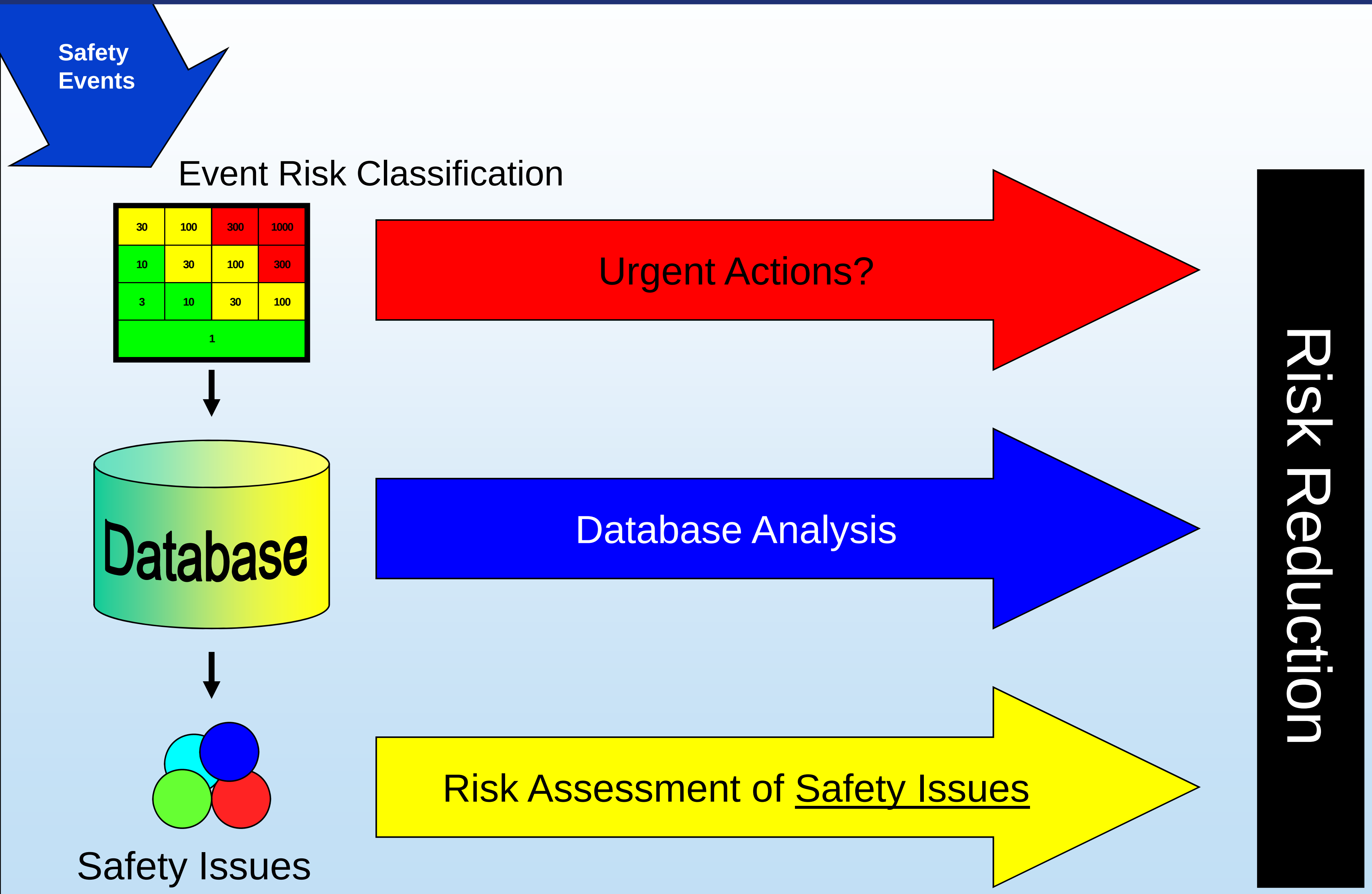
- Importantly, past events as such cannot be *managed*. Safety Management is about managing the *Safety Issues* which cause/contribute to the events.

What is risk assessed?

- In fact, it becomes obvious, that methods are needed for risk assessing *both* Events *and* Safety Issues

- This is clarified by the process description (see next slide):
  - Data comes into the Risk Assessment process *in the form of events*
  - Among the events, there may be some that highlight matters justifying urgent action. Therefore an initial risk assessment needs to carried out *on the events*, immediately when they are received. This step is called Event Risk Classification (ERC).
  - Later in the process, Safety Issues will be identified. These will then have to be risk assessed. This step is called Safety Issue Risk Assessment (SIRA).

Process summary – simplified schematic



Risk assessing *Events*

- *Risk = A state of **uncertainty** where some of the possibilities involve a loss, catastrophe, or other undesirable outcome (Douglas W. Hubbard*)*
- If past events are historical facts, how can they be *risk assessed*, as there should be *no uncertainty*?
- For this purpose, ARMS introduces the concept of Event Based Risk (EBR).
  - EBR is the risk that *was* present in the event *in the moment it took place,* i.e. the risk that it *would have escalated* into an accident outcome
  - EBR relates to an *accident* risk
  - EBR (and its assessment) is completely independent from any other events. It is a property of the single event under study.

*Director of Applied Information Economics (AIE). Author of the #1 bestseller in business math on Amazon: "How to Measure Anything: Finding the Value of Intangibles in Business"

Event Based Risk (EBR)

- EBR reflects how concerning (or frightening) the event was for the organisation in question.
- The two dimensions of EBR are:
  - *How close (to an accident outcome) did it get?*
  - *How bad would it have been (in terms of accident severity)?*

- In other words:
  - What was the Remaining Safety Margin, i.e. effectiveness of *remaining* risk barriers; and,
  - If this had escalated into an accident outcome, what would have been the *most probable* accident outcome?

- These two questions are reflected in the ERC matrix

ERC matrix

Question 2

What was the effectiveness of the remaining barriers between this event and the most credible accident scenario?

Effective	Limited	Minimal	Not effective
50	102	502	2500
10	21	101	500
2	4	20	100
1			

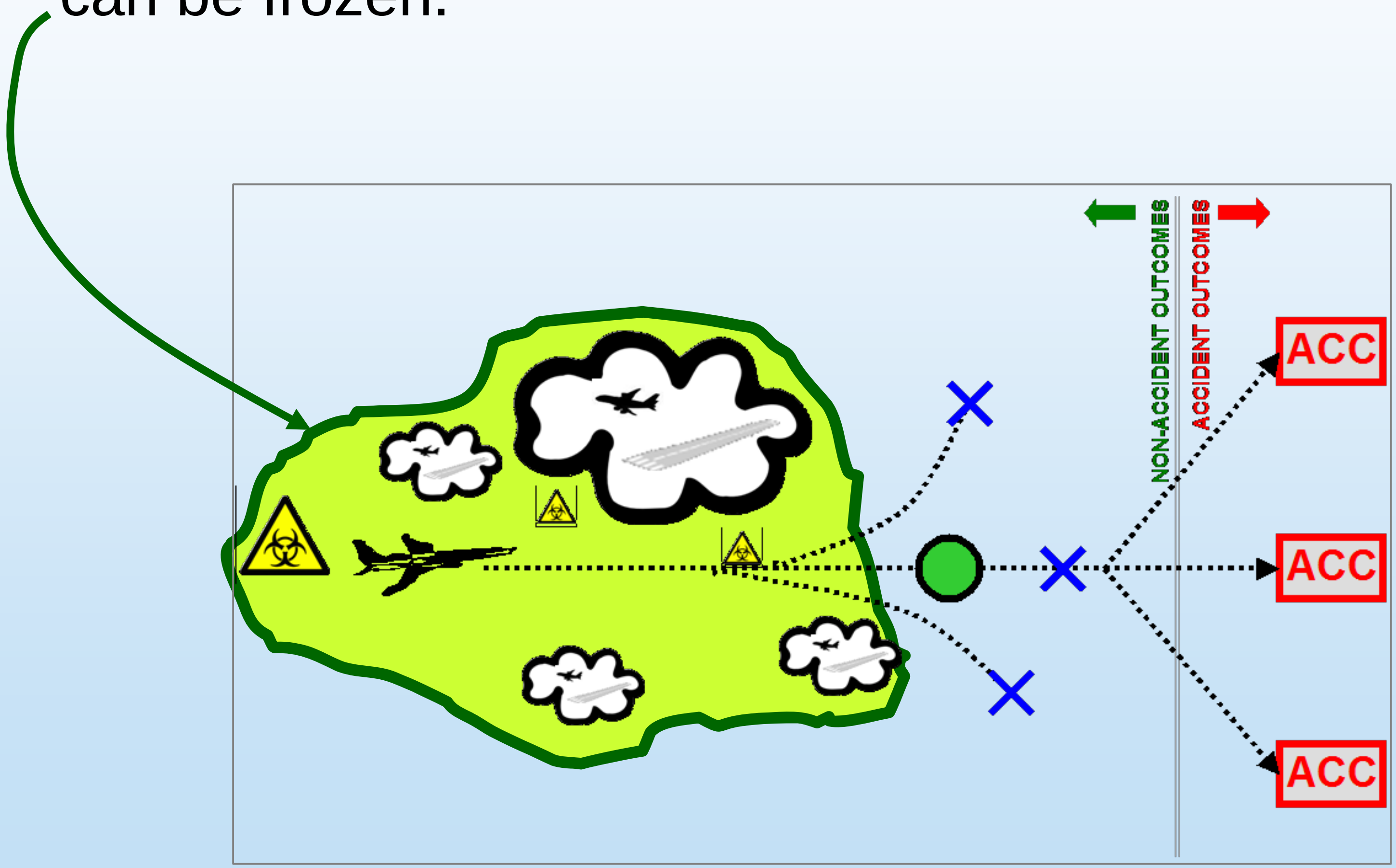
Question 1

If this event had escalated into an accident outcome, what would have been the most credible outcome?

		Typical accident scenarios
Catastrophic Accident	Loss of aircraft or multiple fatalities (3 or more)	Loss of control, mid air collision, uncontrollable fire on board, explosions, total structural failure of the aircraft, collision with terrain
Major Accident	1 or 2 fatalities, multiple serious injuries, major damage to the aircraft	High speed taxiway collision, major turbulence injuries
Minor Injuries or damage	Minor injuries, minor damage to aircraft	Pushback accident, minor weather damage
No accident outcome	No potential damage or injury could occur	Any event which could not escalate into an accident, even if it may have operational consequences (e.g. diversion, delay, individual sickness)

ERC procedure

- Because the assessment is inherent to the one single event under focus, the way it happened, most of the circumstances can be frozen.

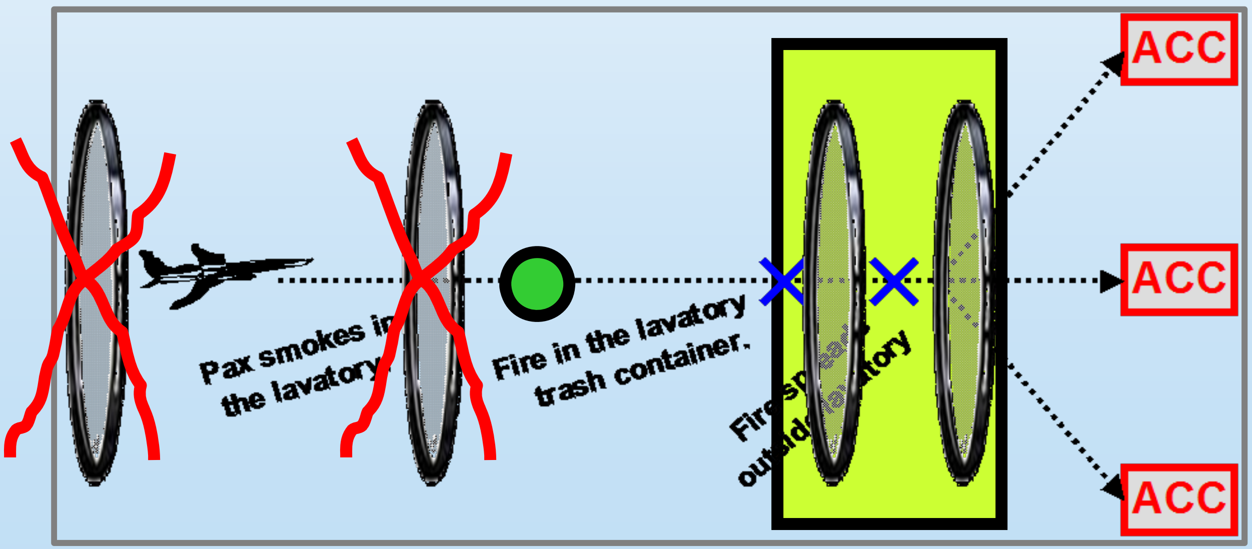


ERC procedure – Question 1

- Think how the event could have escalated into an accident outcome (see examples to the right of the ERC matrix). Typically, the escalation could be due to actions by the people involved, the way the hazard interferes with the flight, and barrier behaviour.
- Do not filter out improbable scenarios. Question 2 will take the (low) probability into account.
- Among the scenarios with an accident outcome, pick the most credible, and select the corresponding row in the matrix.

ERC procedure – Question 2

- To assess the remaining safety margin, consider both the number and robustness of the <u>remaining</u> barriers between this event and the accident scenario identified in Question 1.
- Barriers, which already failed are ignored
- Select the column of choice.



ERC

- More detail about ERC and examples can be found in the ARMS documentation (see e.g. www.skybrary.aero)

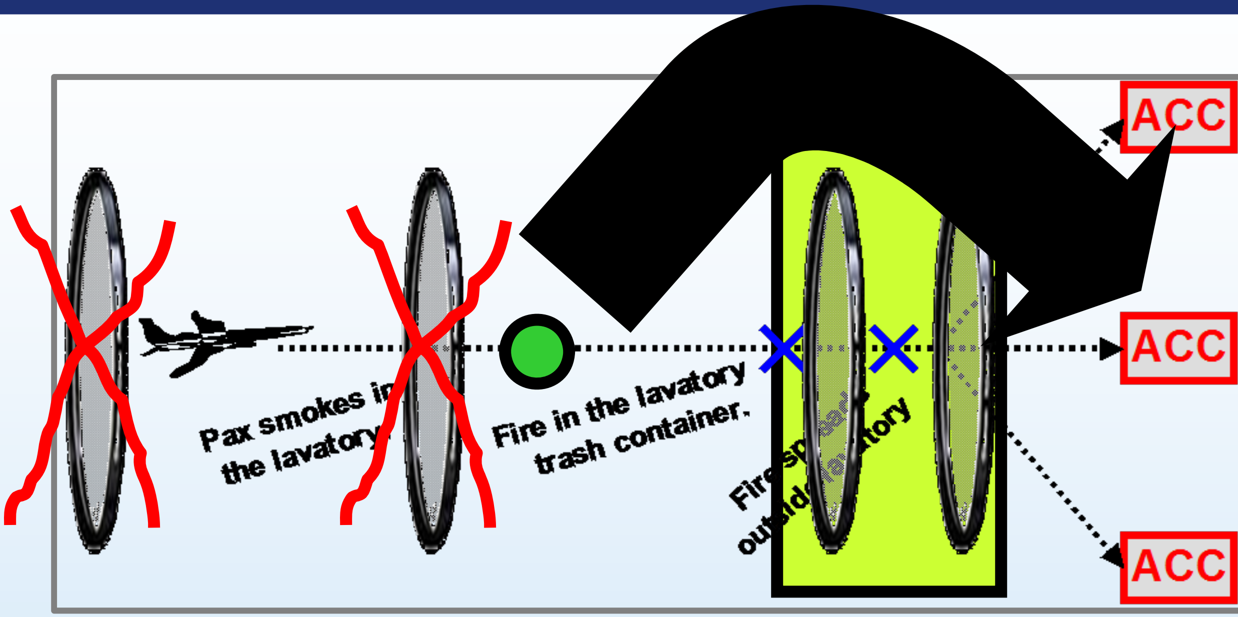
Safety Issue Risk Assessment (SIRA)

- SIRA deals with a <u>Safety Issue</u>, i.e. the object is an issue that the analyst wants to risk assess. It is up to the analyst to define exactly the *scope* of the Safety Issue.
- Therefore, by definition, in SIRA, the object of the risk assessment (the Safety Issue) can be precisely defined.
- The main difference to ERC is that SIRA is dealing not with one event, but a more general issue,and may typically cover several locations, time periods, aircraft types, etc.

- Another difference is that while ERC is about what ***was*** the risk in this event, SIRA is looking into the *future*, asking what ***is*** the risk of this Issue, today and in the future.
- Therefore, typically in ERC some of the *barriers* have already failed, but in SIRA, they are all still considered operational.

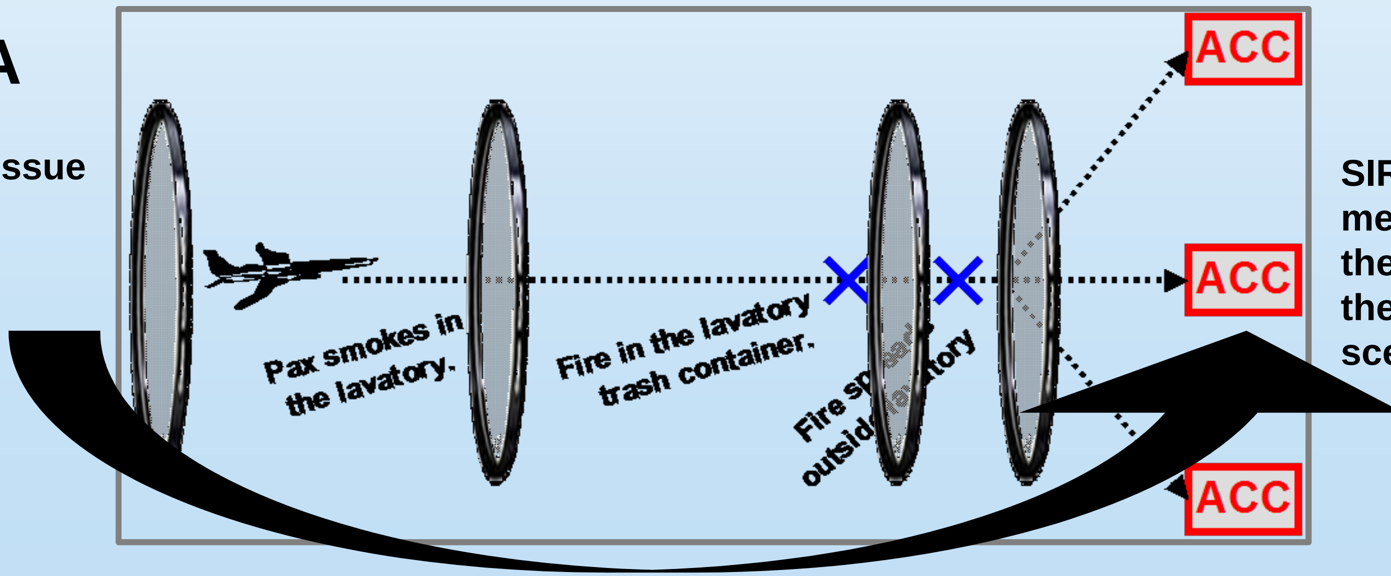
Barriers in ERC vs. SIRA

ERC
for one event



ERC measures the risk of this escalation; in the conditions where the event took place.

SIRA
for Safety Issue



SIRA measures the risk of the whole scenario.

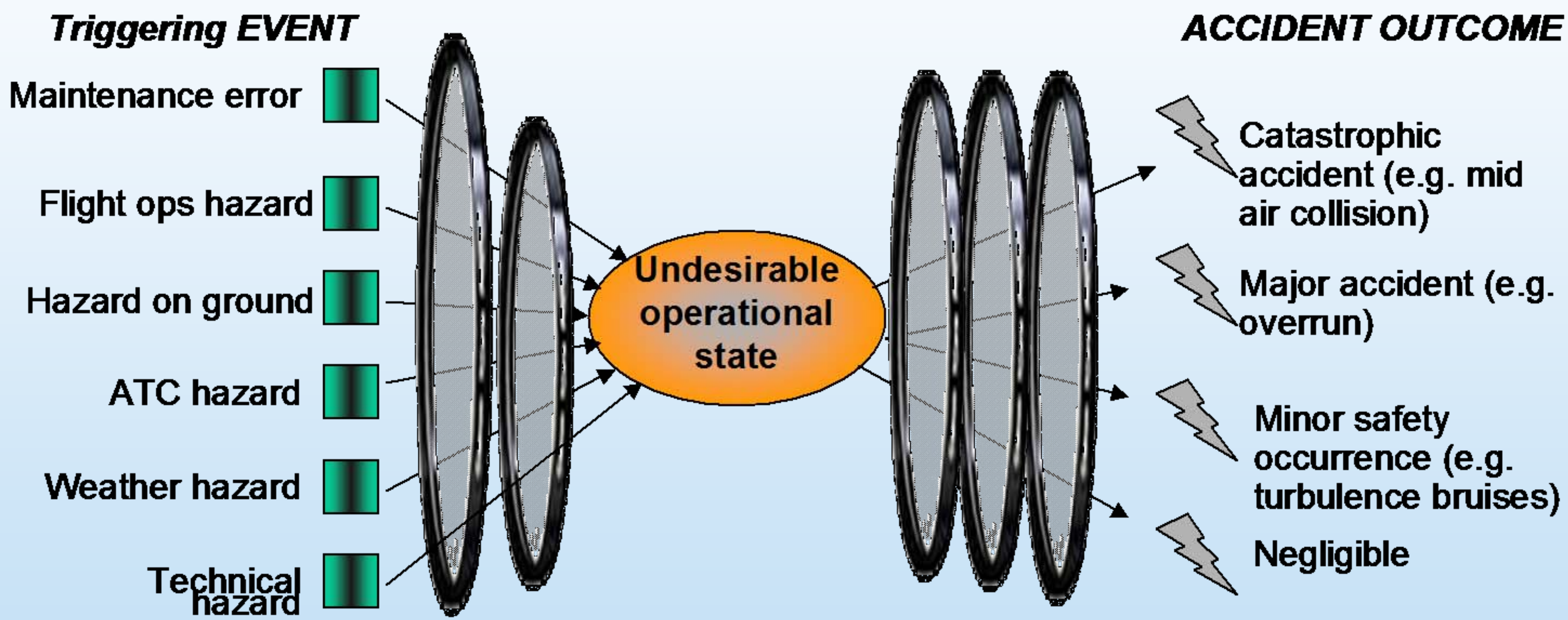
SIRA framework

- In SIRA, the simple *severity x likelihood* formula is expanded to a formula with four factors, which together determine the risk level. (see next slide)
- The two extra factors allow integrating the impact of Barriers in the risk assessment

- Moreover, the meaning of ’frequency’ and ’severity’ become crystal clear:
  - Frequency refers to the frequency of the *triggering event*
  - Severity refers to the severity of the potential *accident outcome* (e.g. and not the severity of some intermediate outcome)

SIRA framework

PREVENT **AVOID** **RECOVER** **(MINIMIZE LOSSES)**



1. FREQUENCY OF TRIGGERING EVENT

2. EFFECTIVENESS OF AVOIDANCE BARRIERS

3. EFFECTIVENESS OF RECOVERY BARRIERS

4. ACCIDENT SEVERITY

Source: ARMS

SIRA procedure

1. Define the Safety Issue precisely:

- Scope the issue in terms of hazards, locations, a/c types, etc.

2. Develop the related potential accident scenarios:

- There may be several accident scenarios within one Safety Issue
- Select the most critical scenarios (one or more) for the risk assessment

Continues on next slide

SIRA procedure

3. Analyse (each) Scenario using the SIRA model:

- Identify the accident outcome of the scenario
- Identify what is considered the triggering event
- Decide what you consider as the UOS.
- List the avoidance and recovery barriers and review their robustness

4. Run the SIRA with numbers:

- Consider using the SIRA Excel tool
- Select a known or an estimated value for each of the 4 SIRA components

SIRA Excel application

- The SIRA framework can be implemented as a tool in different ways. ARMS has created an excel application for SIRA. In this application:
  - *Frequency of the triggering event* is to be chosen from the range

    ”Virtually every flight” - ”About every 10 Million sectors”
  - *Effectiveness of avoidance barriers* from the range:

    ”The barriers will fail...practically always...once every 10 times...etc...once in 10M times”
  - *Effectiveness of recovery barriers* (as avoidance barriers)
  - *Accident severity* from the same four classes as in ERC
  - The result is given on a scale of five risk classes (see next three slides)

SIRA Excel application

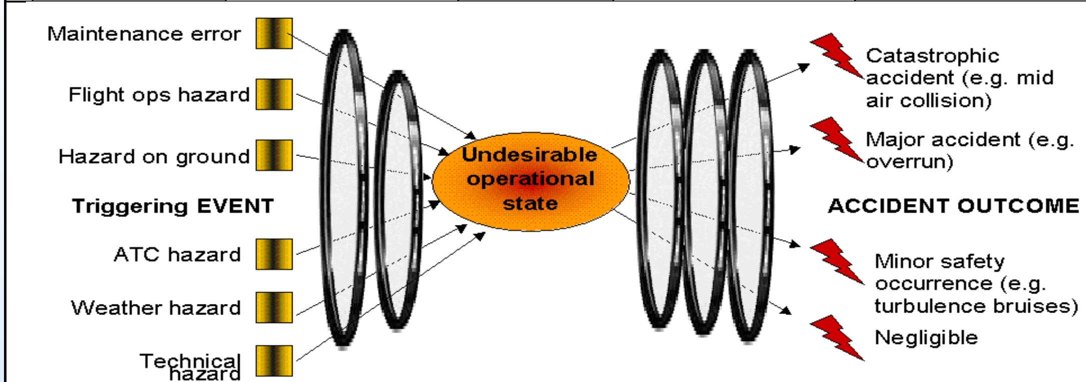
- First, defining the Safety Issue precisely…

1	**Safety Issue title:**	
2	**Define/scope the SI:**	
	Description of Hazard(s)	
	Description of Scenario	
	A/C types	
	Locations	
	Time period under study	
	Other	

SIRA Excel application

- Then, analysing the risk factors and barriers
- Needed figures can be obtained from the event database or estimated

3	**Analysis of potential Accident Scenario**				
	3.1 Triggering event		3.2 Undesirable Operational State		3.3 Accident Outcome

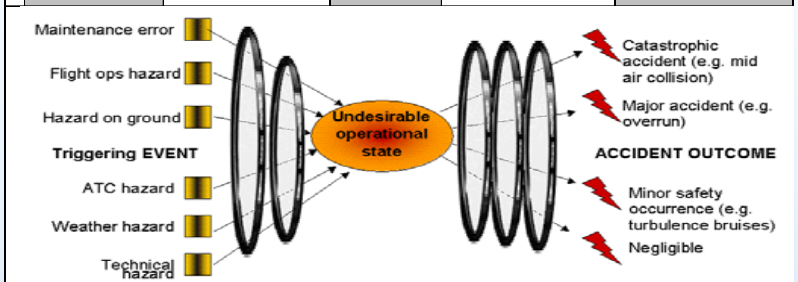


4	**Describe the barriers**				
		4.1 To avoid the UOS		4.2 To recover before the Accident	
5	**Risk Assessment**				
	The estimated frequency of the triggering event (per flight sectors) is:	The barriers will **fail** in AVOIDING the UOS...		The barriers will **fail** in RECOVERING the situation before the ACCIDENT...	The accident severity would be...
	About every 100000 sectors	Once every 10 times		Once every 10 times	Major
	1.E-05	1.E-01		1.E-01	
			UOS frequency:		**Mean Accident frequency:**
			1.E-06		1.E-07
6	**Result**				
	6.1 Resulting risk class	**Secure**			
	Comments on actions:				

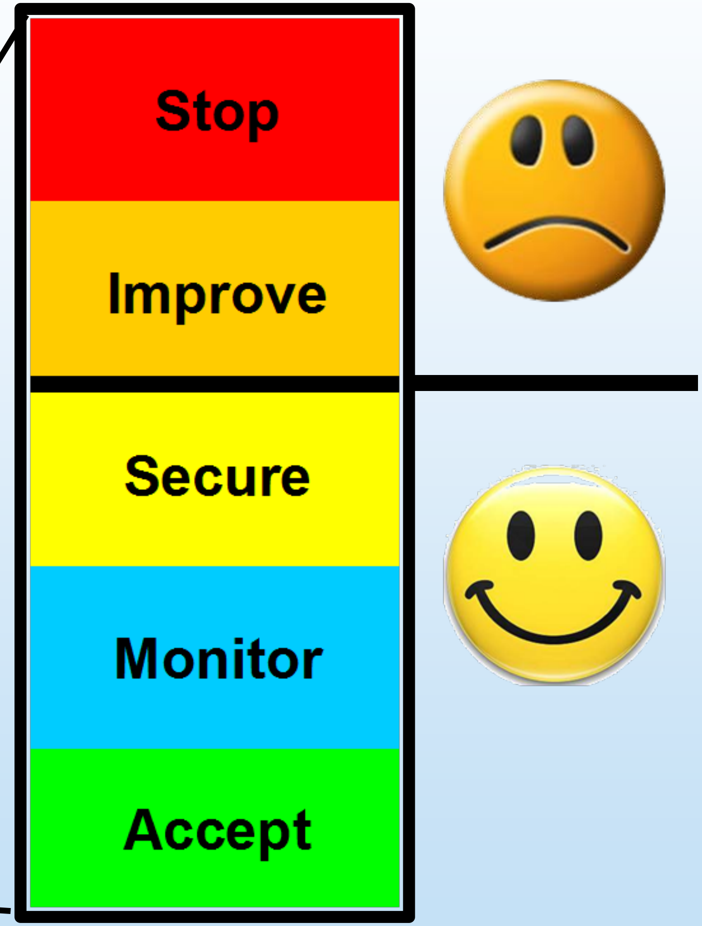
SIRA Excel application

- Obtaining the result:

3	Analysis of potential Accident Scenario				
	3.1 Triggering event		3.2 Undesirable Operational State		3.3 Accident Outcome



4	Describe the barriers				
		4.1 To avoid the UOS		4.2 To recover before the Accident	
5	Risk Assessment				
	The estimated frequency of the triggering event (per flight sectors) is:	The barriers will **fail** in AVOIDING the UOS...		The barriers will **fail** in RECOVERING the situation before the ACCIDENT...	The accident severity would be...
	About every 100000 sectors	Once every 10 times		Once every 10 times	Major
	1.E-05	1.E-01		1.E-01	
			UOS frequency:		Mean Accident frequency:
			1.E-06		1.E-07
6	Result				
	6.1 Resulting risk class	Secure			
	Comments on actions:				



PART THREE

RISK ASSESSMENT USING OLDER METHODS

Pre-ARMS risk assessment methods

- There are numerous proposed techniques for operational risk assessment.
  - There are significant similarities *between* these pre-ARMS techniques
  - They usually consist of a risk matrix and some guidance on how to use it.
  - The two axes in the risk matrix are:
    - Severity
    - Likelihood of (re)occurrence

- The ICAO SMS course material and the ICAO Safety Management Manual provide a good overview of the pre-ARMS practice. The following slides provide extracts.

ICAO SMM 2. edition

- ICAO SMM 2, chapter 5:
  - 5.4.2 Safety risk <u>probability</u> is defined as the likelihood that an unsafe event or condition might occur.
  - Safety risk <u>severity</u> is defined as the possible consequences of an unsafe event or condition, ***taking as reference the worst foreseeable situation***
  - The composite of probability and severity is the safety risk of the consequences of the <u>***hazard***</u> under consideration

(highlighting added)

ICAO SMS course, Module 5: “Risks”, rev. 13

Probability of occurrence		
Qualitative definition	**Meaning**	**Value**
Frequent	Likely to occur many times *(has occurred frequently)*	**5**
Occasional	Likely to occur some times *(has occurred infrequently)*	**4**
Remote	Unlikely, but possible to occur *(has occurred rarely)*	**3**
Improbable	Very unlikely to occur *(not known to have occurred)*	**2**
Extremely improbable	Almost inconceivable that the event will occur	**1**

Severity of occurrences		
Aviation definition	**Meaning**	**Value**
Catastrophic	➢Equipment destroyed. ➢Multiple deaths.	A
Hazardous	➢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. ➢Serious injury. ➢Major equipment damage.	B
Major	➢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. ➢Serious incident. ➢Injury to persons.	C
Minor	➢Nuisance. ➢Operating limitations. ➢Use of emergency procedures. ➢Minor incident.	D
Negligible	➢Little consequences	E

Risk probability		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

ICAO SMM 2. edition

- 9.3.5 The assessment of hazards should take into consideration all possibilities, from the least to the most likely. It has to make adequate allowance for "worst case" conditions, but it is also important that the hazards to be included in the final analysis be "credible" hazards. It is often difficult to define the boundary between a worst credible case and one so dependent on coincidence that it should not be taken into account. The following definitions can be used as a guide in making such decisions:
  - Worst case: The most unfavourable conditions expected, e.g. extremely high levels of traffic, and extreme weather disruption.
  - Credible case: This implies that it is not unreasonable to expect that the assumed combination of extreme conditions will occur within the operational life cycle of the system.

(highlighting added)

Pre-ARMS risk assessment methods

- Such methods are directly derived from the *severity x likelihood* formula – there is no further conceptual framework to support them.

- The same method (and matrix) can be seen applied on:
  - ***Historical events*** (e.g. examples in the ICAO SMS Course, Module 5 “Risks”, Rev 13)
  - ***Planned changes*** (ICAO SMM 2.ed., chapter 5, app.1 “Anycity intl. airport construction plan”)
  - ***Safety Assessments*** of current operation (ICAO SMM 2.ed., chapter 5, app.2 “Converging runways operation”)

- The next two slides illustrate these examples

Pre-ARMS methods – applied on a historical event

Warm-up exercise N° 05/01

❖ Scenario:

➢ Fuel spill on the apron area surface of approximately 25 m (75 ft) length and 5 m (15 ft) width, produced by an A310 ready to pushback and taxi for departure

❖ Report by the apron responsible person:

➢ After the A310 pushback the spill was contained and the apron area was decontaminated

Warm-up exercise N°05/01 – results

1. Identify the hazard(s)
   - Fuel spill
2. Determine the hazard(s) consequence(s)
   - a) Fire
   - b) Contamination
   - c) Sliding vehicle
3. Assess the probability of the risk: a) Fire → **Remote**
4. Assess the severity of the risk → **Hazardous**
5. Determine the resulting risk index → **3B**
6. Establish the risk tolerability → **Acceptable based on risk mitigation. It might require management decision**

Source: ICAO SMS course, R13, Module 5.

Pre-ARMS methods – applied on an issue

ANYCITY INTERNATIONAL AIRPORT CONSTRUCTION PLAN

SCENARIO

Anycity International Airport (AIA) has two parallel runways, one main and one secondary, and is planning to install drainage near the approach end of the secondary runway. Construction vehicles must cross the primary runway to gain access to the construction site. Because there are numerous operations during the day, a decision is made to do work at night, during lighter traffic, to avoid disruption of day operations. The AIA Safety Manager must evaluate the safety consequences of the plan for night construction of the drainage.

AIA Safety Action Group (SAG) has been tasked to support the AIA Safety Manager in evaluating the safety consequences of the construction plan. One immediate and obvious generic area of concern is the movement of construction vehicles to and from the work site that could lead to runway incursions. The SAG applies a safety risk management process to evaluate the safety consequences of the construction plan.

CONVERGING RUNWAYS OPERATION

SCENARIO

An air traffic service provider has received feedback from airport users expressing safety concerns regarding converging runways operations at XYZ International Airport. XYZ International Airport consists of three runways, 08L/26R, 08R/26L, and 12/30 (see Figure 1 hereunder). Converging runway operations are occasionally conducted for runways 26R and 12. The air traffic service provider has requested its Safety Manager to re-evaluate the safety of the converging runway operations procedures for runways 26R and 12 at XYZ International Airport under the light of the concerns expressed by users.

Source: ICAO SMM, 2.edition draft, chapter 5

Pre-ARMS methods – applied on an issue

Type of operation or activity	Generic hazard	Specific components of the hazard	Hazard-related consequences	Existing defences to control risk(s) and risk index	Further action to reduce risk(s) and resulting risk index
Airport operations	Airport construction	Construction vehicles crossing primary runway	a) Construction vehicles may deviate from prescribed procedure and cross the primary runway without an escort. b) Aircraft could conflict with a crossing vehicle.	1. The SAG assessment leads to the conclusion that there is a remote probability that a construction vehicle will deviate from prescribed guidelines and cross the primary runway without an escort. 2. There are night air carrier operations at the airport, so there is a remote probability that an aircraft would conflict with a crossing vehicle. 3. While the probability of an aircraft/construction vehicle conflict is remote, the SAG assesses that, should such conflict occur, the severity of the occurrence could be catastrophic. 4. The SAG assesses existing defences (driver training programme, use of escorts for construction vehicles, signs, markings and lighting). 5. Using the Safety Risk Assessment Matrix (Chapter 5, Figure 5-4) and the Safety Risk Tolerability Matrix (Chapter 5, Figure 5-5), the SAG assesses: **Risk index:** *3A* **Risk tolerability:** *Unacceptable under the existing circumstances*	1. The SAG decides to control the safety risk by using an existing aerodrome perimeter road to gain access to the construction site. All construction vehicles will be escorted on the perimeter road. 2. With this mitigation, the SAG reassesses the probability of construction vehicles crossing the primary runway without an escort, or that aircraft could conflict with a crossing vehicle, as extremely improbable. Nevertheless, should an aircraft/construction vehicle conflict occur, the severity of such occurrence would still be catastrophic. 3. Use of the perimeter road as mitigation may delay construction vehicles due to added driving distance, but in the assessment of the SAG: a) while it does not entirely remove the possibility of the consequences of the hazard from occurring (construction vehicles may still cross the primary runway due to a number or combination of circumstances); b) it nevertheless brings the safety risks of the consequences (construction vehicle deviating from prescribed procedure and crossing the primary runway without an escort; and aircraft in conflict with a crossing vehicle) to an acceptable level. 4. Using the Safety Risk Assessment Matrix (Chapter 5, Figure 5-4) and the Safety Risk Tolerability Matrix (Chapter 5, Figure 5-5), the SAG re-assesses: **Risk index:** *1A* **Risk tolerability:** *Acceptable* 5. The SAG documents this decision process for future follow-up with the Anycity International Airport Safety Manager.

Type of operation or activity	Generic hazard	Specific components of the hazard	Hazard-related consequences	Existing defences to control risk(s) and risk index	Further action to reduce risk(s) and resulting risk index
Air traffic control activities	Converging flight paths on Runways 26R-08L and 12, irrespective of aircraft on approach or departure	a) Aircraft rejects landing on 26R against traffic landing on 12. b) Aircraft takes off on 26R against traffic landing on 12. c) Aircraft approaches 08L against traffic landing on 12. d) An aircraft conducts a "side step" from an approach on Runway 08L to 08R or 08R to 08L against traffic landing on 12.	a) Wake turbulence encounter. b) Evasive action to avoid other traffic. c) Loss of control following maneuver to avoid other traffic. d) Runway overrun following an unstable approach. e) Midair collision at the departure end of Runway 26R between aircraft approaching 12 and aircraft approaching 08L or departing 26R (worst case consequence).	• Controller coordination procedures; • Increased spacing to protect airspace for missed approaches during adverse weather; • Restrictions on arrivals on Runway 12 when Runway 26R is used for departures; • Aerodrome Surface Detection Equipment (ASDE); • Runway Incursion Prevention Programme and Wildlife Control Programme; • Airside driver initial and recurrent training and testing; • Continual monitoring and statistical follow up of cross-wind limits; • Availability and use of approach radar; • Standards for runway occupancy time; • Separate tower frequencies; and [illegible] a) Wake turbulence encounter: **Risk index:** 3C **Risk tolerability:** Acceptable based on risk mitigation b) Evasive action to avoid other traffic: **Risk index:** 3C **Risk tolerability:** Acceptable based on risk mitigation c) Loss of control following maneuv[er] to avoid other traffic: **Risk index:** 3B **Risk tolerability:** Acceptable based on risk mitigation d) Runway overrun following an unstable approach: **Risk index:** 3B **Risk tolerability:** Acceptable based on risk mitigation e) Midair collision at the departure end of Runaway 26R between aircraft approaching 12 and aircraft approaching 08L or departing 26R: **Risk index:** 2A **Risk tolerability:** Acceptable based on risk mitigation	a) Initiate a continuing campaign to encourage flight crews to pass PIREPS to air traffic control units when weather conditions differ from those forecast or expected; b) Study the appropriateness and effectiveness of the implementation of a Converging Runway Display Aid (CRDA) as an essential safety and capacity enhancement device at XYZ International Airport; c) If CRDA is not implemented at XYZ International Airport, establish separation criteria and procedures for adjusting the landing aircraft spacing such that an aircraft that may reject a landing on runway 26R has protected airspace from aircraft that may be approaching runway 12; [d]) Depict a range of approach speed constraints on arrival type charts; and modify air traffic controller communication procedures so traffic on 08L-26R being advised of intersecting traffic on runway 12. [e]) Install an emergency frequency override so that one controller can switch to other controller's frequency to issue emergency instructions.

PART FOUR

ADVANTAGES OF ARMS COMPARED TO OLDER METHODS

Problem 1: Risk Assessing Events or Issues?

- At first sight, many pre-ARMS methods seem to work properly.
- Closer examination shows the shortcomings:

- Let’s first look at the first example of chapter 3 (slide 42) with **an historical event** (fuel spill). A good way to start discovering the limitations of the method, is to ask ”what risk did we actually assess?” *(”risk of what?”):*
  - Is this result (”3B”) applicable for A310 only? For this airport only?
  - Is it applicable for all kinds of fuel spills?

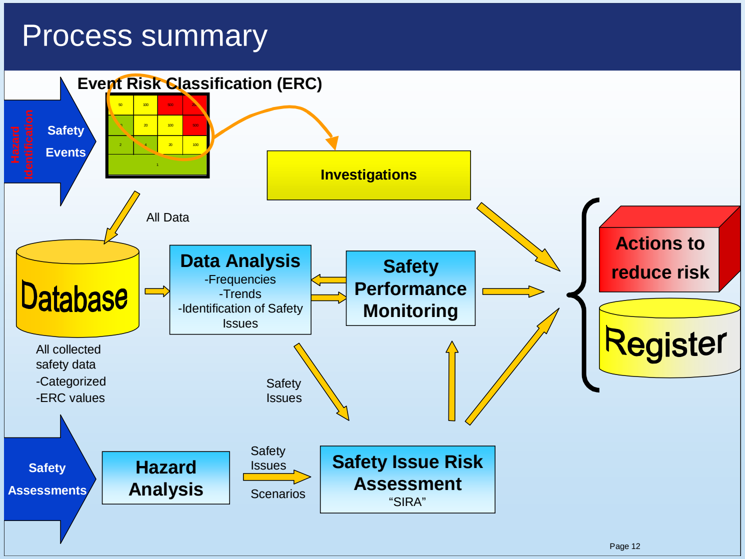
There is no clear answer.

Problem 1: Due to a lacking conceptual framework, there is no distinction between risk assessment on ***events*** vs. ***safety issues***

Problem 1 solved with ARMS

- Clear distinction between Event Risk Classification (ERC) and Safety Issue Risk Assessment (SIRA):
  - ERC applied on **Events**
  - SIRA applied on **Safety Issues**

- The role of both ERC and SIRA within the Risk Assessment Process is clearly explained



Problem 2: Risk assessing single events

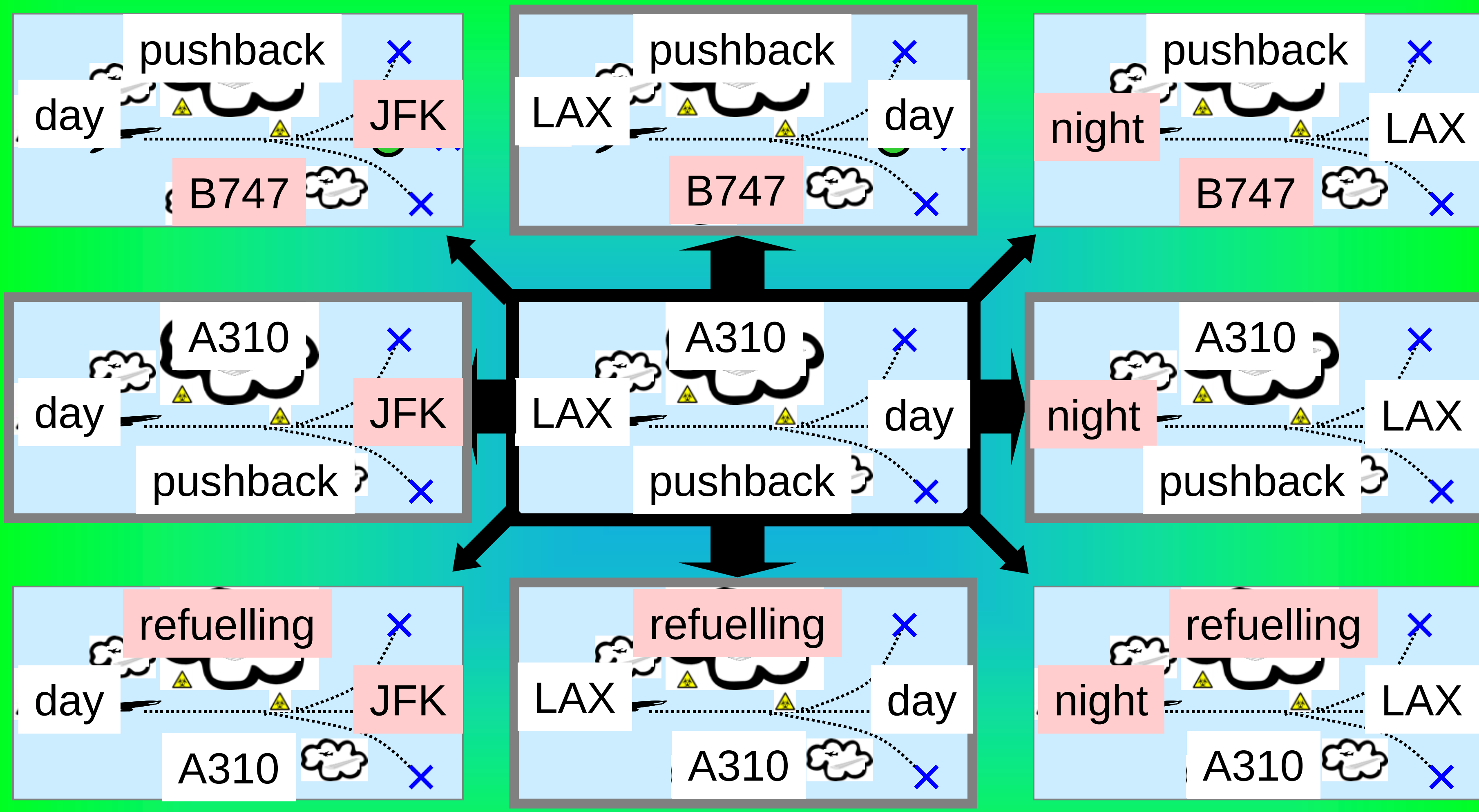
- In a classic risk matrix, one axis is about likelihood (of reoccurrence) with options like ”frequent”. But frequency is not a property of one **single** historical event!

- This is another indication of *conceptual unclarity*. It reveals that, in reality, the classic risk assessment of a single event is about ”what is the risk that *something similar* would happen in the future”.

- This is a shaky starting point for a risk assessment because it is not clear what exactly is risk assessed. ”Something similar” could mean literally hundreds of different variations.

- Example on the next slide illustrates an event which took place on a A310 in LAX during pushback in daytime (center square). Just by varying these factors, dozens of ”similar” events can be imagined.

Event and ”something similar”



Problem 2: Risk assessing single events

- Due to this conceptual weakness, single event risk analysis is faced with the ”*severity of what*” and ”*likelihood of what*” syndromes.

- To illustrate this, let’s look at the fuel spill case (slide 42). The Safety Analyst has to answer:
  - *Severity of <u>what</u>*: the actual outcome (fuel spill only)? A “credible” escalation (vehicle slide or fire with damage but without fatalities)? Worst case scenario (fire with fatalities)? …
  - *Likelihood of what*: fuel spill? Sliding vehicle? A fire? A fatal fire?

- Problem 2 is complicated by problem 1:
  - Are the severity/likelihood determined only for A310 and this airport etc. or for some other variations...?

Problem 2 solved by ERC

- The Event Risk Classification solves this problem because both axes in the ERC matrix *relate only to the one single event*.

- Also, the *circumstances* are taken as they were, so the ”endless variations” problem is avoided.
  - The risk assessment is now based on factual elements, not on vague imagined variations.

- These advantages reduce subjectivity significantly, even if some subjectivity remains in judging:
  - Whether an escalation into an accident was possible
  - The strength of the remaining barriers

Problem 2 solved by ERC

- Let us apply ERC to the fuel spill example on slide 43
  - Situation: A310, no jetty (ready for push back), engines not running, large full spill under aircraft
  - Question 1: fire under the aircraft and its consequences would be the most credible accident outcome, with ”Major” outcome.
  - Question 2:
    - Fire will not start without an igniter, and ignition sources are few and/or forbidden
    - If the fire started later, the plane would no longer be on the fuel
    - Cabin integrity gives time before an external fire penetrates
    - Some exits (and possibly the jetty) available for evacuation
    - → ”Limited” barrier effectiveness
- Result: “yellow” with risk index 21.
  - Therefore, requires “further investigation” of the event

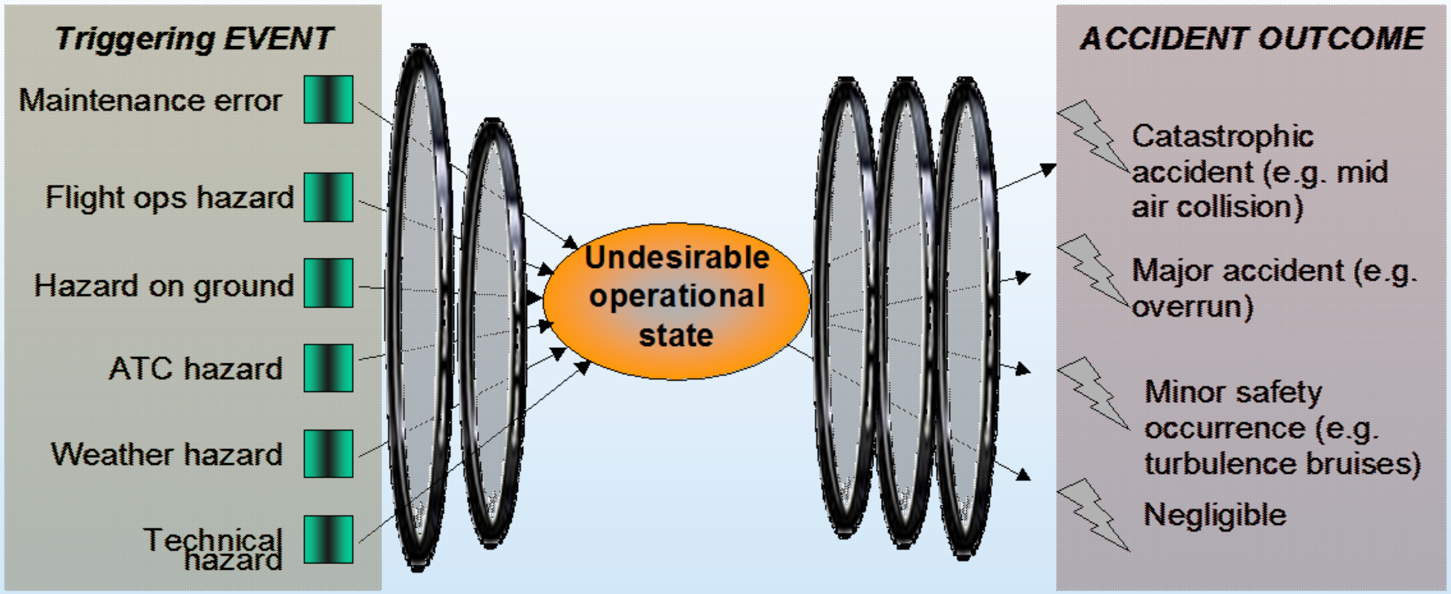
Problem 3: No structure to risk assess *Issues*

- Pre-ARMS:
  - ***No framework*** is available to structure the risk assessment of Safety Issues - factor by factor.
  - The severity-likelihood formula does not explicitly take into account the Barriers

- Example: 2nd ICAO (slides 43-44): all risks concluded "*acceptable based on risk mitigation*", but:
  - How is it assessed/quantified that the mitigation is good enough to attain "acceptable" risk level?
  - How can anyone else follow the logic and reasoning of the assessment, step-by-step, afterwards?

Problem 3 solved by SIRA

- SIRA has a solid framework to structure the risk analysis, factor by factor



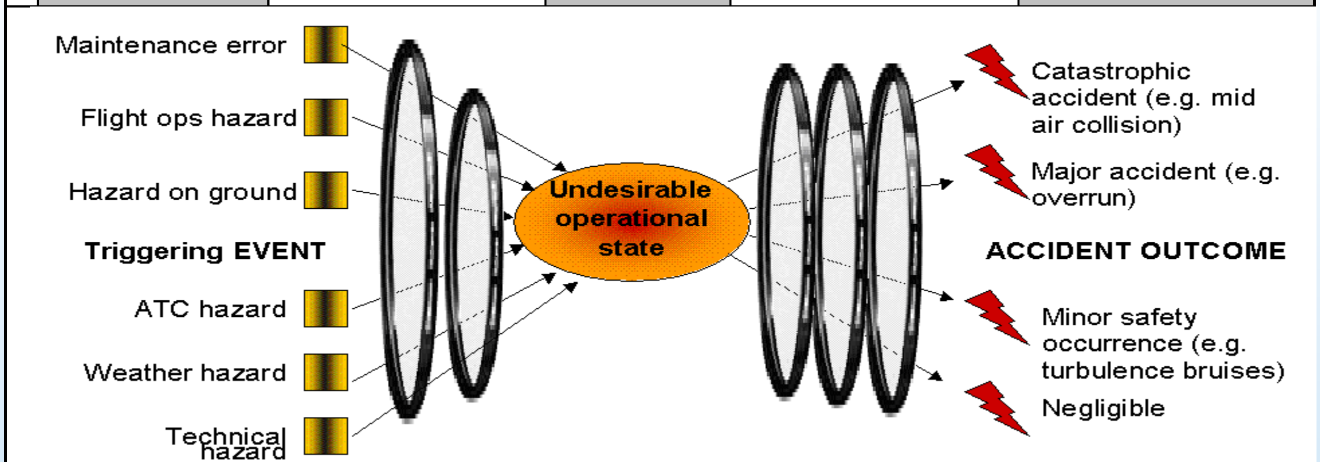
→Each of the four factors is analysed, one-by-one, and the results are recorded on the SIRA sheet.

→ Barriers are described explicitly and their effectiveness is assessed

→ The reasoning can be studied afterwards and challenged.

Problem 3 solved by SIRA

3	**Analysis of potential Accident Scenario**				
	3.1 Triggering event		3.2 Undesirable Operational State		3.3 Accident Outcome
	Maintenance error where both command and monitoring channels are cross-connected.		**Taking off with an aircraft with the above maintenance error**		**Loss of control at takeoff after liftoff.**



4	**Describe the barriers**				
		4.1 To avoid the UOS		4.2 To recover before the Accident	
		The maintenance team is supposed to make an operational check after the maintenance task. This barrier could fail either because the check is omitted or not done carefully enough (“it moves” is not enough, the direction needs to be correct). Estimated conservative failure rate is: 1/100 times. During taxi-out, the pilots make a flight controls check. This may fail for the same reasons as for the maintenance team. The estimated failure rate is the same 1/100.		· The Recovery Barrier consists of two things: either only one side is affected and by luck the Pilot Not Flying (PNF) side; or the PF manages to control the aircraft despite the cross-connection. This is deemed very difficult and subject to wind effects just after lift-off.	

SIRA Excel tool:

- → Analysis of each factor, one-by-one
- → Barriers described and analysed

Problem 4: No quantification

- Pre-ARMS:
  - While Risk Assessing Issues, the result is based solely on ***qualitative*** judgment
  - This increases subjectivity due to several reasons:

Meaning
Likely to occur many times *(has occurred frequently)*
Likely to occur some times *(has occurred infrequently)*
Unlikely, but possible to occur *(has occurred rarely)*
Very unlikely to occur *(not known to have occurred)*
Almost inconceivable that the event will occur

Meaning
➢Equipment destroyed. ➢Multiple deaths.
➢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. ➢Serious injury. ➢Major equipment damage.
➢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. ➢Serious incident. ➢Injury to persons.
➢Nuisance. ➢Operating limitations. ➢Use of emergency procedures. ➢Minor incident.
➢Little consequences

- *Verbal, non-quantified guidance* (e.g. “rarely”) tends not to decrease subjectivity.
- Large matrix size (5x5) worsens the problem
- Guidance relating to *detailed <u>actual</u> outcome* (e.g. “injury”) is easy to use, but sometimes leads to incorrect classification:
  - i.e. a near-miss in the air has <u>no</u> actual outcome (no injury, damage, etc).

Problem 4 solved by SIRA

- SIRA uses a numerical quantification of each factor
- Factor-of-10 difference between classes makes judgment easier

5	**Risk Assessment**				
	The estimated frequency of the triggering event (per flight sectors) is:	The barriers will **fail** in AVOIDING the UOS...		The barriers will **fail** in RECOVERING the situation before the ACCIDENT...	The accident severity would be...
	About every 100000 sectors	Once every 10 times		Once every 10 times	Major
	1.E-05	**1.E-01**		**1.E-01**	

Problem 5: Risk tolerability decision

- Pre-ARMS:
  - The risk tolerability decision is not anchored to any recognised quantified industry reference

Risk probability		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

Why here?

Problem 5 solved by SIRA

- The SIRA Excel tool uses recognised JAR/FAR-1309 risk tolerability limits:
  - Catastrophic: 10^{-9}
  - Major: 10^{-7}
  - Minor: 10^{-5}

Problem 6: Safety Assessments

- Safety Assessments are risk assessments for a planned change
  - For example, starting a new route to a new destination
- Effectively, the change is a potential ”Safety Issue” and Safety Assessments are Safety Issue Risk Assessments for a future issue.
- Therefore, problems 3-5 are applicable also to Safety Assessments using pre-ARMS methods.
  - For example, how can anyone else follow the logic and reasoning of the assessment, step-by-step, afterwards?

Problem 6 solved by SIRA

- SIRA can often be used to carry out Safety Assessments and overcome problems 3-5.

  - SIRA works when there are enough factual, quantifiable elements to feed it (e.g. new GPWS recovery procedure)

  - For purely qualitative “soft” changes (e.g. change of management structure or outsourcing a service) it may be impossible to quantify the risk using SIRA or any other such method. In such cases a fully qualitative but “as objective as possible” estimate must be made using a defined process, typically in an evaluation group.

Problem 7: Lack of global visibility on risks

- The pre-ARMS methods are not well adapted to producing meaningful and reliable high level overviews of operational risks, for example:
  - Trend of total operational risk over last 12 months
  - Risk by route or by a/c type
  - Runway overrun risk by destination airport
  - Global risk picture of all Safety Issues with risk trends

Problem 7 solved with ARMS

- ARMS Methodology provides two good sources for creating global risk overviews:
  - ERC risk indeces: every event in the database has a risk value. Therefore, statistics which used to reflect only event numbers/rates can now be enhanced to reflect the total risk.
  - SIRA results: risk of each Safety Issue and its evolution can be plotted on a global risk map

- Results from ERC and SIRA can be used separately and in combination to build Safety Performance indeces tracking the total operational risk.

Conclusions

- Whilst the ARMS Methodology will not remove all subjectivity from the Risk Assessment in aviation, it is believed that it is significantly more objective than the other methods currently in use in aviation.

- This is due to factors such as:
  - Logical conceptual framework as a base
  - Guiding the Safety Analyst in assessing risk in a structured and systematic manner, based on the correct criteria
  - Making the subjective risk assessment judgments visible and debatable
  - Quantifying risk in numbers and benchmarking with established industry references for risk tolerability.