Network Manager
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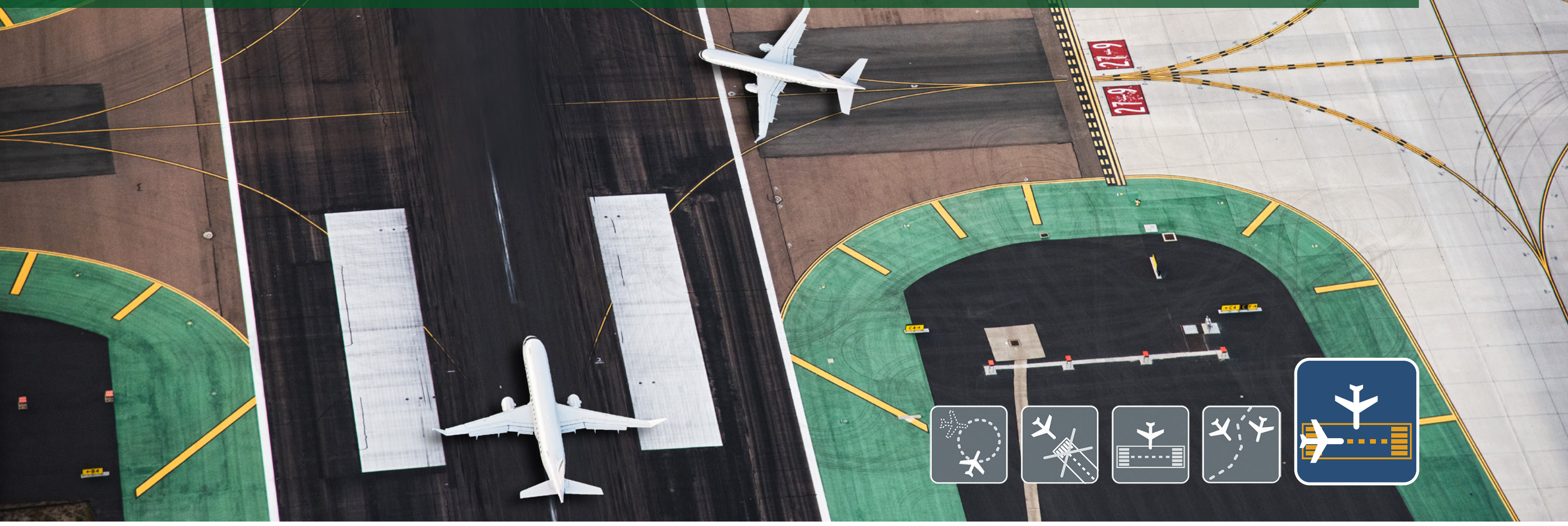
Operational Safety Study

Sudden High Energy Runway Conflict (SHERC)



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Operational Safety Study:

Sudden High Energy Runway Conflict

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The following table identifies all management authorities who have successively approved the present issue of this document.

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0.1	28/04/16		Creation of the Working Draft	All
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CONTENTS

Executive Summary

The EUROCONTROL Safety Improvement Sub-Group (SISG), reporting to the EUROCONTROL Safety Team, was tasked to identify the Top 5 ATM Operational Safety Priorities.

SISG performed a series of reviews during summer 2014 and involved a series of dedicated workshops with 14 ANSPs, representing a large part of European air traffic.

The analysed sample includes 57 runway incursion incidents of which 13 were classified as severity A and 44 classified as severity B. The 2014 EUROCONTROL AST data shows there were 101 runway incursions severity A or B reported incidents. Of these, 25 were classified as severity A and 76 incidents as severity B. Thus the study is based on detailed analysis of more than half of the total Severity A+B runway incursion reported to EUROCONTROL by all States.

As a result of the SAFMAP analysis, the Top 5 priority areas were suggested, agreed by SISG and endorsed by the Safety Team:

- Risk of operation without transponder or with a dysfunctional one
- **Sudden High Energy Runway Conflict**
- Controller Detection of potential runway conflict
- “Blind spot” – inefficient conflict detection with the closest aircraft
- ACAS RA not followed

The purpose of this report is twofold:

- To document the Operational Safety Study on the second of the Network Manager operational safety priorities for 2015/16 – “Sudden High Energy Runway Conflict”.
- To serve as a reference for the Network actors in case they undertake operational safety analysis and improvement activities regarding the risk related to Sudden High Energy Runway Conflict.

The methodology employed was as follows:

- Generate a set of generic scenarios from possible scenario sources, mechanisms and outcomes.
- Consider what barriers exist that if implemented and deployed correctly could prevent a Sudden High Energy Runway Conflict.
- Consider what barriers exist that if implemented and deployed correctly could mitigate the impact of a Sudden High Energy Runway Conflict.
- Analysis of each generic scenario against the potential barriers to establish which of these barriers could be most effective over the whole range of scenarios.
- Detail and analyse a set of actual events to validate that the barriers suggested by the generic scenario analysis, are or are not the same barriers that are the most effective in the live environment.
- Consider current industry best practice and known future developments.
- Draw conclusions from the study and make recommendations to stakeholders.

This study concurs with and supports the FAA National Runway Safety Plan conclusion that an incorporation of multiple layers of technology is currently the most effective response to Sudden High Energy Runway Conflicts.

This study identified twelve barriers available that could potentially prevent runway incursions that, if not halted, could escalate into Sudden High Energy Runway Conflict events. It was established that no barrier by itself has the potential to prevent more than 35% of identified potential scenarios.

It is concluded therefore that a combination/s of the following barriers have the highest potential to prevent Sudden High Energy Runway Conflicts.

- ATC Conformance Monitoring and Conflicting Clearances Alerts.
- The correct use of ATC memory aids.
- The use of stop bars 24H together with procedures never to cross an illuminated bar.
- Autonomous Runway Incursion Warning Systems (such as Runway Status Lights).
- Flight deck Airport Moving Maps.

The study identified seven barriers that might mitigate the collision risk. Once a Sudden High Energy Runway Conflict event had been initiated, almost all of them relied upon belated visual detection from aircrew/drivers for collision avoidance.

There is currently no functionality available that will provide timely alerts involving movement on two intersecting runways. It is concluded therefore that there is currently a lack of an effective system barrier that can make a significant impact in reducing the risk of collision.

Visual detection by ATC of SHERC events is limited by meteorological conditions and is unlikely to be effective once the event has been initiated. It is concluded therefore that ATC training should emphasise the importance of ***Prevention*** of SHERC events, focussing on the correct use of memory aids, visual vigilance and precise ATC clearances.

The use of stop bars 24H together with procedures to never cross a lit stop bar or to give a clearance across a lit stop bar could have prevented half of the actual serious runway incursions studied. It is concluded therefore that there are significant safety gains available from this established safety barrier with appropriate procedures.

Recommendations are made that:

- European ANSPs and Airport Authorities review the identified potential barriers and the conclusions in case they undertake operational safety analysis and improvement activities for Sudden High Energy Runway Conflict events.
- European ANSPs and the EUROCONTROL Safety Improvement Sub-Group (SISG) monitor occurrences involving Sudden High Energy Runway Conflict to determine changes in frequency and severity.
- All European industry stakeholders support the development of procedures tools and functionality that may have the potential to prevent or mitigate the high collision risk that is present in Sudden High Energy Runway Conflicts.
- All European industry stakeholders promote and support the deployment and use of runway stop bars with procedures to never cross an illuminated stop bar or to give a clearance across an illuminated stop bar, subject to contingency procedures.
- All European industry stakeholders to note that the consistent use of memory aids, correct and precise phraseology and visual vigilance by both ATC and Pilots/Drivers can combine to create a strong preventative barrier. Training and competence programmes should reinforce these essential activities.

Chapter 1
Introduction

1.1 What is the purpose of this document?

Documenting and communicating.

This purpose of this report is twofold:

- To document the operational safety study on one of the Top 5 Network Manager operational safety priorities for 2015/2016 – "Sudden High Energy Runway Conflict (SHERC)"
- To serve as a reference for the Network actors in case they undertake operational safety analysis and improvement activities for Sudden High Energy Runway Conflict (SHERC) events.

1.2 What are the Network Manager Top 5 ATM Operational Safety Priorities for 2015/2016?

1. ***Risk of operation without transponder or with a dysfunctional one***

Operations without transponder or with a dysfunctional one constitute a single threat with a potential of "passing" through all the existing safety barriers up to "see and avoid".

2. ***Sudden High Energy Runway Conflict***

The scenario typically involves a runway conflict in which, once initiated, the time available to ATC to prevent a collision is likely to be less than the time so needed.

3. *Controller detection of potential runway conflict*

Some Runway Incursion incidents could be prevented if controllers had better means to detect that the runway was occupied.

4. *"Blind spot" – inefficient conflict detection with the closest aircraft*

Loss of separation "Blind Spot" events are typically characterised by the controller not detecting a conflict with the closest aircraft. They usually occur when a controller is focussed on a "future situation" and has filtered out the most immediate aircraft.

5. *ACAS RA not followed*

Losses of Separation in the En-Route environment sometimes involve "ACAS RA not followed by one or more flight crews". Coordinated RA generation and response is an essential safety barrier; however, some events include a failure to follow the RA correctly or not following the RA at all.

1.3 How was the 'Top 5' identified?

The Network Manager identifies Network safety issues to enable aviation stakeholders to identify existing hazards and anticipate new operational risks

Our ultimate goal is to keep the Network safe and able to increase its capacity and efficiency.

The EUROCONTROL Safety Improvement Sub-Group (SISG), reporting to the EUROCONTROL Safety Team, is tasked to identify the Top 5 ATM Operational Safety Priorities. The SISG followed a structured two-step process of operational safety prioritisation. Firstly SISG identified a list of priority areas.

The first step was to define broad priority areas for further prioritisation.

The agreed list contains work priority areas addressing operational threats, safety precursors or undesired safety outcomes. The list includes:

- Airspace Infringement
- Runway Incursion
- Loss of Separation
- ATC sector overloads
- Level Bust
- Severe Weather Risk
- Air Ground communications
- Runway Excursion

The second step was a detailed review with SAFMAPS.

The list of agreed priority areas contained issues that are too broad to be a part of a focussed work program. There was a need to get more "granularity" and select some of the areas for a detailed review. Based on the availability of reliable safety information, two of the risk areas were selected for detailed review:

- "Runway Incursion" and
- "Loss of Separation En-Route".

SISG performed a series of reviews during summer 2014 including a series of dedicated workshops with 14 ANSPs, representing a large part of European air traffic. It can be concluded that the analysed sample of incidents is sufficiently representative for the overall population of incidents in Europe.

Comprehensive barrier models – Safety Functions Maps (SAFMAPs) - were developed and populated with representative data from the participating ANSPs. The incident data is for high severity (classified as 'A' and 'B') events, which are on one side thoroughly investigated and on the other side – highly informative because the incident scenarios 'test' the majority of the available safety barriers.

As a result of the SAFMAP analysis, the Top 5 priority areas were suggested, agreed by SISG and endorsed by the Safety Team:

- Risk of operation without transponder or with a dysfunctional one
- Sudden High-Energy Runway Conflict
- Controller Detection of occupied runway
- "Blind spot" – inefficient conflict detection with the closest aircraft
- ACAS RA not followed

Why was Sudden High Energy Runway Conflict selected?

EUROCONTROL took a sample of 57 High severity runway incursions. (14 Severity A events and 43 Severity B events).

- 12 of the incidents in the sample (21%) incidents involved sudden, high energy runway conflicts. The scenario typically involves a runway conflict in which, once initiated, the time available to ATC to prevent a collision is likely to be less than the time so needed.
- 3 of the 14 incidents that were classified as Severity A involved sudden, high energy runway conflicts.
- One of the 3 incidents resolved by providence involved sudden, high energy runway conflict.
- It was therefore decided to select "Sudden, high energy runway conflict" as a safety priority.

Chapter 2
Study Scope

2.1 Scope

A Sudden High Energy Runway Conflict (SHERC) scenario typically involves a runway conflict in which, once initiated, the time available to ATC to prevent a collision is likely to be less than the time so needed.

For the purposes of this study it is necessary to define a Scope within which runway incursions can be designated as SHERC events. All of the following criteria need to be satisfied:

- Sudden
- High Energy
- Available Time close to Needed Time
- Short Duration of event
- Separation criteria at CPA
- Evidence of Collision Avoidance

2.2 Sudden

In order for the event to be categorised as ‘Sudden’:

- A landing aircraft should be not more than 600ft/2nm final at the time of the incursion; this broadly accords with the FAROS (Final Approach Runway Occupancy Signal) acquisition protocol of 500ft.
- An aircraft cleared for take-off must be already lined-up at the time of the runway incursion.

2.3 High Energy

In order for the event to be categorised as ‘High Energy’:

- In the case of an aircraft taking off; it must have reached at least 80kts at the time of the pilot becoming aware of the conflict.
- In the case of a landing aircraft; it must have an IAS of at least 100kts at the time of the pilot becoming aware of the conflict.

2.4 Available time for Conflict Resolution close to Needed Time

2.4.1 Needed time to detect a conflict and come to a halt

ATC or a pilot may become aware of the conflict very early purely by visual detection. However, if detection comes as a result of a system alert, research shows that the average time for ATC to react to an alert and communicate is 6.9 secs (within one standard deviation).

The same research concluded that the average time for a pilot to subsequently react is 2.3 seconds. The average time from alert to the commencement of deceleration is therefore up to 9.2 seconds. For landing aircraft, from commencement of deceleration on landing to stopping is about 500m (evidence from actual events and peer review). This is worked from reducing from 120kts with maximum braking. The rate of deceleration is not a straight line, braking becoming more efficient as the speed reduces. The average comes out at 30m per second and a total of 17 seconds. The time needed from alert to stopping after landing from 120kts is therefore 26 seconds. (9+17). For aircraft on a take-off roll, from commencement of deceleration to stopping is less as rejected take-off is deemed to start at 80kts. The average comes out at 12 seconds. The time needed from alert to stop on take-off roll from 80kts is therefore up to 21 seconds. (9+12).

2.4.2 Available time to detect a conflict and come to a halt

The stated criteria for a SHERC is that the time available to ATC to prevent a collision is likely to be less than the time so needed. These times will vary for each event depending upon the circumstances e.g. the relative position of the aircraft/vehicle incurring upon the runway and the position of take-off or landing.

2.5 Short Duration of Undesired presence

The vehicle or second aircraft should not have been on the runway for more than 30 seconds before the “incursion” i.e. the clearance to land or take-off. This caveat removes the events where an airport operations vehicle has been present on the runway for some time.

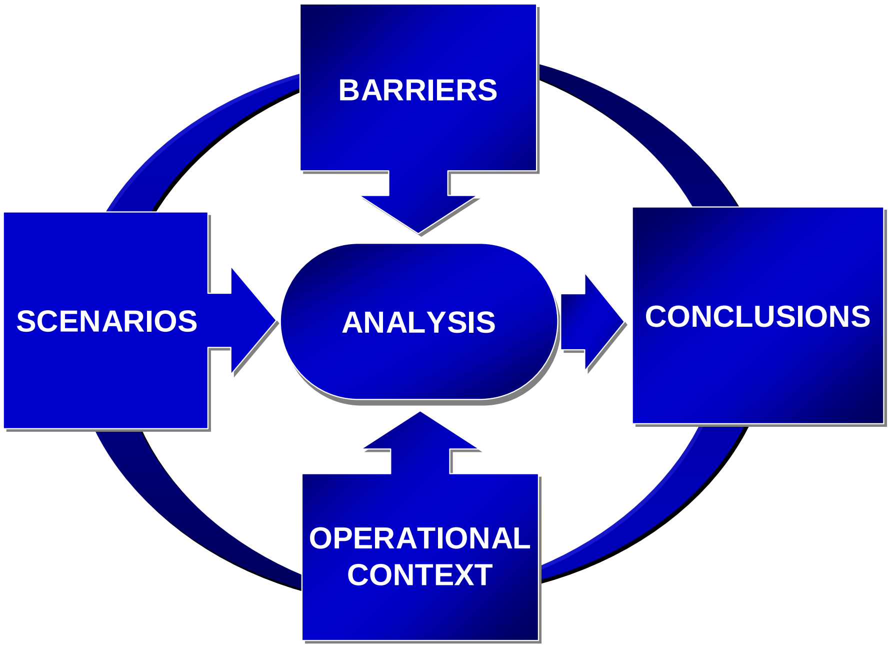
2.6 Separation remaining at CPA (Closest Point of Approach)

In order for the event to be considered a SHERC, the minimum separation remaining at CPA should be not more than 500m or 400ft vertically.

2.7 Collision avoidance

In order for the event to be considered a SHERC, there must be evidence of deliberate action taken to avoid the collision or increase the minimum distance at CPA. A sighting report with no apparent deviation from the norm is <u>not</u> a SHERC.

Chapter 3:
The Generic Process



A generic process was designed to analyse ATM Operational Safety Priorities (the Top 5) as to provide a common methodology for assessment and evaluation. The process starts with three preparatory steps:

- Identification of the operational context pertaining to the operational area considered.
- Definition of the operational scenarios.
- Identification of safety barriers (both preventing and mitigating the effect of the event).

Once all those data are collated an analysis of effectiveness of barriers against the identified operational scenarios will be performed and correlated with analysis of real life occurrences. Once the analysis is complete the study will provide the conclusions.

Chapter 4
Operational Context

4.1 Operational Contexts

The operational contexts that may affect the efficiency of barriers

The local operational contexts with relevance for the present study are identified as follows:

- Availability of ATC surveillance information.
- Visibility from the Tower (including Line of Sight, Obstructions, Lighting).
- Runway configurations.
- ATC Safety Net Alerts.
- Airport Ground Safety Nets and Operating Procedures.
- Pilot Safety Nets.

4.2 ATC Surveillance information

The level of ATC service may differ depending on equipage

The availability of surveillance data affects the likelihood of detection of RWY incursions and conflicts.

- Basic Surface Movement Radar (SMR).
- Airport Surface Movement & Detection System (such as A-SMGCS).
- Integrated Tower Working Positions incorporating Conformance and Clearance Alerts.

4.3 Visibility conditions from the Tower

The possibility of ATC recognising potential threats in good time may differ depending upon visual impairment

The visibility from the Tower Visual Control Room (VCR) and subsequent ability to recognise potential conflicts can be limited by:

- Day/Night.
- Fog/Mist.
- Low Cloud affecting high control towers.
- Sunlight and glare during day.
- Precipitation on windows.
- Airport lighting during night operations, especially temporary work in progress.
- Line of Sight and Obstructions.
- Remote Cameras.

4.4 Runway configurations

Runway configurations could impact upon complexity and performance

The configuration of the runways can influence how the operations on each runway can be affected by the operations on any adjacent ones and therefore how the specific barriers can be applied:

- Multiple Parallel/Intersecting runways.
- Mixed mode/Single mode operations.

4.5 ATC Safety Net alerts

Availability and presentation of Safety Alerts to ATC could impact upon the timeliness of conflict detection and resolution

The availability and functionality of ATC Safety Net Alerts can differ extensively including the following:

- Airport Surface Movement & Detection System (such as A-SMGCS level 2).
- Airport Surface Movement & Predictive Detection System (such as A-SMGCS level 3-4):
  - Conflicting ATC Clearances Alerts (CATC).
  - Conformance Monitoring Alerts for Controllers (CMAC).
- Sensor Controlled Incursion Projection System (SCIPS).

4.6 Airport Ground Safety Nets and Operating Procedures

The availability of Airport Ground Safety Systems could impact upon the prevention and mitigation of events

Airport Ground Safety Systems and the method of operation chosen can influence both the likelihood of conflict prevention and conflict mitigation:

- Illuminated Stop Bars and operational procedures.
- Runway Guard Lights.
- Runway Ahead Signage/Markings.
- Autonomous Runway Incursion Warning System (ARIWS) such as:
  - Runway Status Lights (RWSL).
    - Runway Entry Lights (REL).
    - Take-off Hold Lights (THL).
  - Final Approach Runway Occupancy Signal (FAROS).
  - Sensor Controlled Incursion Projection System (SCIPS).

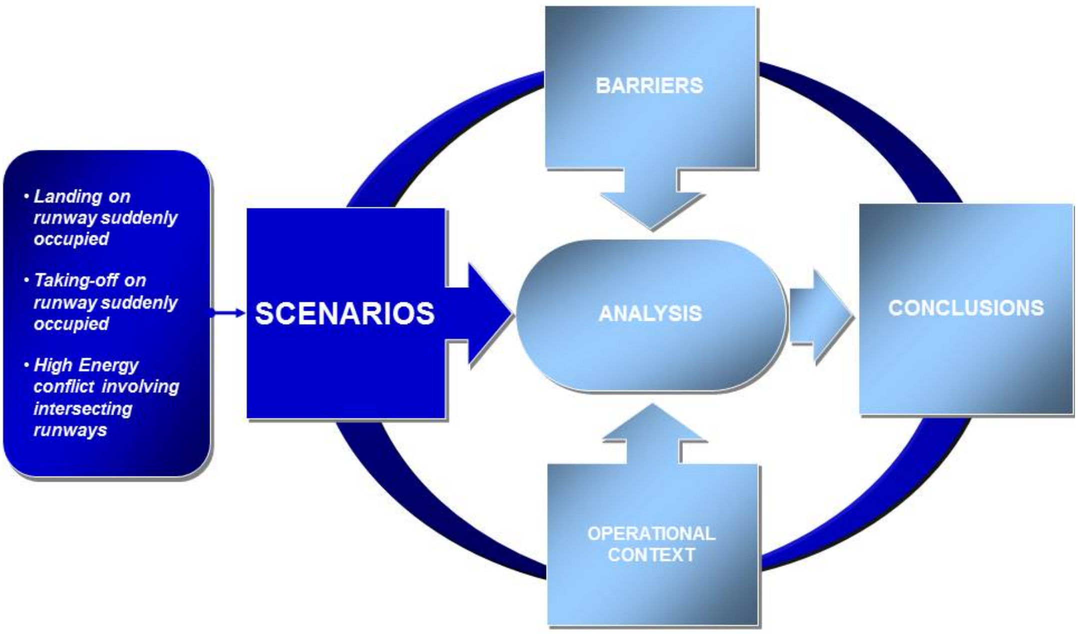
4.7 Pilot Flight Deck Safety Nets

The availability of Flight Deck Airport Information Systems could impact upon the prevention and mitigation of events

Flight Deck Airport Information Systems and the method of operation chosen can influence both the likelihood of conflict prevention and conflict mitigation:

- 3D Airport Moving Maps on Primary Flight Display.
- 2D Airport Moving Maps on Navigation Display.
- Taxi Wizard.
- SmartRunway and SmartLanding.

Chapter 5
Generic Scenarios



5.1 How should generic operational scenarios be defined?

Generic operational scenarios are needed to deconstruct the complexity of analysis. Scenario definition is specific to help decide the efficiency of the safety barriers whilst generic enough to keep their number relatively small. The definition of generic operational scenarios takes the form of a synthesis of two sources of information:

Combination of top-down and bottom-up approaches

- A systematic analytical break-down of the operational scenario into sub-scenarios. This is based on all theoretically possible combinations of the scenario (1) sources, (2) mechanisms and (3) outcomes.
- A review of the publicly available information from investigation reports of accidents and serious incidents investigated following the provisions of ICAO Annex 13 and confidentially provided data in respect of less significant incidents.

5.2 Analytical deconstruction of operational scenarios

Scenario Sources

The following could lead to a potential SHERC generic scenario:

A. An incorrect ATC clearance to either an aircraft landing/taking-off, or an aircraft/vehicle on the ground resulting in an incorrect presence on the runway.

B. A non-conformance with an ATC clearance by an aircraft landing/taking-off, or by an aircraft/vehicle on the ground, due to spatial/positional confusion, resulting in an incorrect presence on the runway.

C. A non-conformance with ATC clearance by an aircraft landing/taking-off, or by an aircraft/vehicle on the ground, due to misinterpretation or mishear of the clearance, resulting in an incorrect presence on the runway

D. A non-conformance with ATC clearance by an aircraft landing/taking-off, or by an aircraft/vehicle on the ground, due poor CRM and/or incorrect execution of the plan, resulting in an incorrect presence on the runway.

Scenario Mechanisms

The mechanisms as a scenario element describe the flight after the scenario sources occurred. In this case the actors may be in one of, or a combination of, the following situations:

- During Take-off.
- During Landing.

The scenario sources are not necessarily applicable to all scenario mechanisms and the various valid combinations will be reflected by the generic operational scenarios.

Scenario Outcome

The traffic situation related to the Sudden High Energy Runway Conflict can be described by one of the following options:

1. Landing on occupied runway

a) Authorised Aircraft/Vehicle on runway.

b) Unauthorised Aircraft/vehicle on runway.

2. Taking-off on occupied runway

a) Authorised Aircraft/Vehicle on runway.

b) Unauthorised Aircraft/vehicle on runway.

3. High speed conflict involving intersecting runways

a) Taking-off/Taking-off on intersecting runways.

b) Taking-off/Landing on intersecting runways.

c) Landing/Landing on intersecting runways.

5.3 Combining the scenario sources and mechanisms result in operational scenario outcomes

1. Landing on runway suddenly occupied

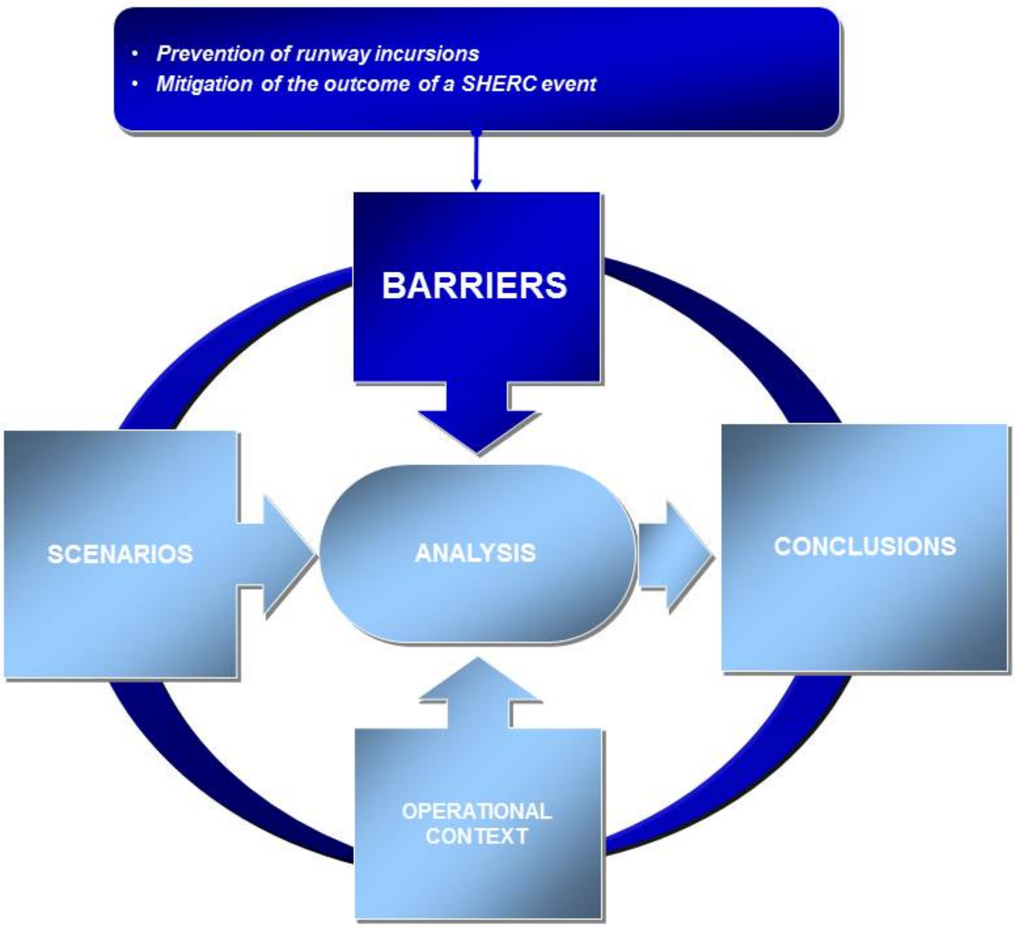
A1a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, ATC incorrectly clear aircraft on short final to land.
A1b	Aircraft cleared to land on short final or landing. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.
B1a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, aircraft is on short final or landing contrary to its ATC clearance due spatial/positional confusion.
B1b	Aircraft cleared to land, on short final or landing, as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due spatial/positional confusion.
C1a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, aircraft lands contrary to its ATC clearance due to misinterpretation or mishear of the clearance.
C1b	Aircraft cleared to land, on short final or landing, as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance.
D1a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, aircraft lands contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.
D1b	Aircraft cleared to land, on short final or landing, as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.

	A2a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, ATC incorrectly clear an aircraft that is lined up to take-off.
	A2b	Aircraft that is lined up is cleared for take-off or has commenced take-off. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.
	B2a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, aircraft commences take-off contrary to its ATC clearance due spatial/positional confusion on a runway.
	B2b	Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due spatial/positional confusion.
2. Taking-off on runway suddenly occupied	**C2a**	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, aircraft commences take-off contrary to its ATC clearance due to misinterpretation or mishear of the clearance.
	C2b	Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance.
	D2a	Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, aircraft commences take-off contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.
	D2b	Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.

	A3a	Taking-off/Taking-off High Energy conflict on intersecting runways after an incorrect ATC clearance.
	A3b	Taking-off/Landing High Energy conflict on intersecting runways after an incorrect ATC clearance.
	A3c	Landing/Landing High Energy conflict on intersecting runways after an incorrect ATC clearance.
3. High Energy conflict involving intersecting runways	**B3a**	Taking-off/Taking-off High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to spatial/positional confusion
	B3b	Taking-off/Landing High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to spatial/positional confusion
	B3c	Landing/Landing High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to spatial/positional confusion
	C3a	Taking-off/Taking-off High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to a misinterpretation or mishear of clearance.

C3b	Taking-off/Landing High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to a misinterpretation or mishear of clearance.
C3c	Landing/Landing High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to a misinterpretation or mishear of clearance.
D3a	Taking-off/Taking-off High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to poor CRM and/or incorrect execution of the plan.
D3b	Taking-off/Landing High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to poor CRM and/or incorrect execution of the plan
D3c	Landing/Landing High Energy conflict on intersecting runways after a non-conformance with an ATC clearance due to poor CRM and/or incorrect execution of the plan.

Chapter 6
Barriers



6.1 Barriers are opportunities

The barriers are not recommendations

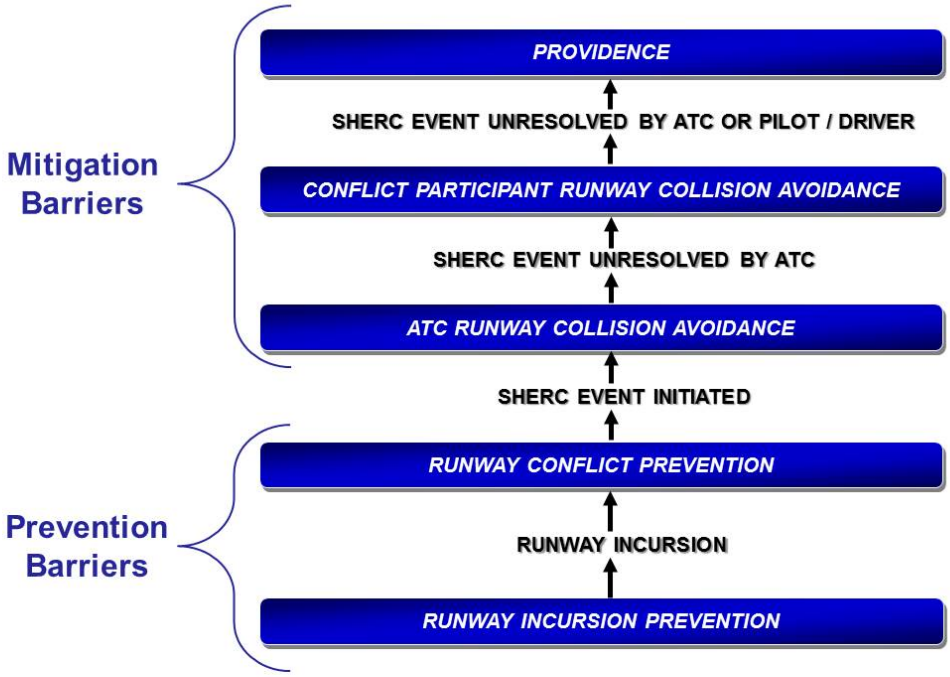
The Barriers included in this risk review have been identified as possible ways that detection of a potential SHERC event could be employed and/or the consequences mitigated.

Their inclusion does not imply that they are relevant to all situations and neither does it imply that promotion of their adoption by airport operators, or ANSPs, would necessarily be appropriate. It may be possible to identify more potentially useful barriers than are included here.

A barrier model

In order to define the barrier there is a need first to define the generic barrier groups for reducing the risk of detection of potential SHERC events. The figure below represents a generalised SAFMAP for Prevention and Resolution of Runway Incursions.

This generalised SAFMAP is derived from the Level 0 Runway Collision SAFMAP Version 0.8 and is the most generic barrier model for preventing runway collision because of situations of detection of occupied RWY.



6.2 Two types of barriers

Balancing preventing and mitigating the risk associated with runway incursions

There are two major sets of barriers which can reduce the risk associated with runway safety events. These barriers are identified based on a wide literature search and consultation, and are:

- Prevention of Sudden High Energy Runway Conflicts. These barriers, when deployed and employed correctly, are capable of alerting ATC, Pilots and Drivers in time to prevent a SHERC event.

- Mitigation of the collision risk of Sudden High Energy Runway Conflicts. These barriers, when deployed and employed correctly, are capable of alerting ATC, Pilots and Drivers to the initial stages of a SHERC in sufficient time to act in order to prevent a collision.

6.3 Barriers preventing Sudden High Energy Runway Conflict (PB)

The Study identifies 12 separate barriers that have the potential to prevent runway incursions that may otherwise develop into Sudden High Energy Runway Conflicts:

- Prevention Barriers (PB) 1 – 6 are barriers principally directed to ATC as prevention opportunities.
- Prevention Barriers (PB) 7 – 11 are barriers principally directed to pilots and drivers as prevention opportunities.
- Prevention Barriers (PB) 12 is principally directed to all users as Airport Procedures.

Two other Generic Barriers are identified:

- PBR: Correct use of RTF.
- PBP: Correct use of ATC or Airport Operating Procedures.

Barriers to prevent runway incursion that could otherwise have resulted in a SHERC	**PB1**	**ATCO memory aids** for runway occupancy by standardised flight data displays including dedicated runway bays, blocking strips etc.
	PB2	**ATCO direct visual detection**
	PB3	**ATCO visual detection using remote camera displays**
	PB4	**Aerodrome traffic awareness including surveillance and runway incursion detection and alerting** (such as A-SMGCS level 2)
	PB5	**Aerodrome traffic awareness including surveillance and predictive runway incursion detection and alerting.** This includes ground positioning and route awareness; situational displays with aircraft and vehicles position and taxi route, surface guidance and navigation (such as A-SMGCS levels 3 and 4).
	PB6	**ATC Clearance Conformance Monitoring Alerts and Confliction Detection.** Use of input and display of the ATC clearances that enable the use of "early warning" surveillance and data to highlight to ATC non-conformance to clearance and the potential consequences of an incorrect clearance. **PB6a: Conformance Monitoring Alerts (CMA)** **PB6b: Conflicting ATC Clearance Alert (CATC)**

	PB7	**Pilot/Driver detection and report**
	PB8	**Final Approach Runway Occupancy Signal (FAROS**.) This providing a visual signal to aircraft on final approach to land that the runway ahead is occupied by another aircraft or a vehicle. This is done by adapting the VASI or PAPI system to alter from steady lights to flashing mode whilst the identified hazard remains.
	PB9	**Autonomous Runway Incursion Warning System (ARIWS)** A system which provides autonomous detection of a potential incursion or of the occupancy of an active runway and a direct warning to a flight crew or a vehicle operator. (ICAO Annexe 14). **Runway Status Lights (RWSL)** is a type of autonomous runway incursion warning system (ARIWS). The two basic visual components of RWSL are Runway Entrance Lights (RELs) and Take-off Hold Lights (THLs). Either may be installed by itself, but the two components are designed to be complementary to each other. **B9a: Take Off Hold Lights (THLs).** These are positioned in the runway departure area to provide an indication to pilots and vehicle drivers that the runway is unsafe for take-off. They consist of red unidirectional lights installed in two longitudinal rows of 16 lights each aligned with and offset either side of the runway centreline lighting. **PB9b: Runway Entrance Lights (RELs**). These are installed at taxiway/runway intersections commencing just before runway holding points to provide an indication when it is unsafe to enter the runway.
	PB10	**SmartRunway and SmartLanding[1]:** This is a software enhancement of Runway Awareness and Advisory System (RAAS) available on later-model Enhanced Ground Proximity Warning Systems. In this context, it provides information to pilots on which runway is ahead both airborne and on the ground.
	PB11	**Airport Moving Maps[2]** **PB11a: 2D with traffic.** Positioned on pilot's Navigational Display this shows airfield layout, position of base aircraft and other aircraft/vehicles including direction of travel. **PB11b: 3D GPS without traffic.** Positioned on pilot's Primary Flight Display. It is similar to automobile GPS but includes track, speed, and height and runway designator. **PB11c: Taxi Wizard.** Shows the pilot planned taxy route from apron to runway holding point. Input via Datalink or manually.
	PB12	**24H use of illuminated stop bars** and robust procedures to never cross a lit stop bar and for ATC never to clear an aircraft/vehicle to cross a lit stop bar.

[1] Used with permission from Honeywell International Inc.
[2] Used with permission from Honeywell International Inc

	PBR*	**Correct use of RTF.** This barrier is not included in the Generic Analysis but is used to earmark events where correct use of RTF may have prevented the incursion.
	PBP*	**Correct use of Procedures.** This barrier is not included in the Generic Analysis but is used to earmark events where correct use of ATC and Airport procedures may have prevented the incursion

6.4 Barriers mitigating the risk of collision that has been initiated by Sudden High Energy Runway Conflict event (MB)

The Study identifies 8 separate barriers that have the potential to mitigate the outcome of a Sudden High Energy Runway Conflict once it has commenced.

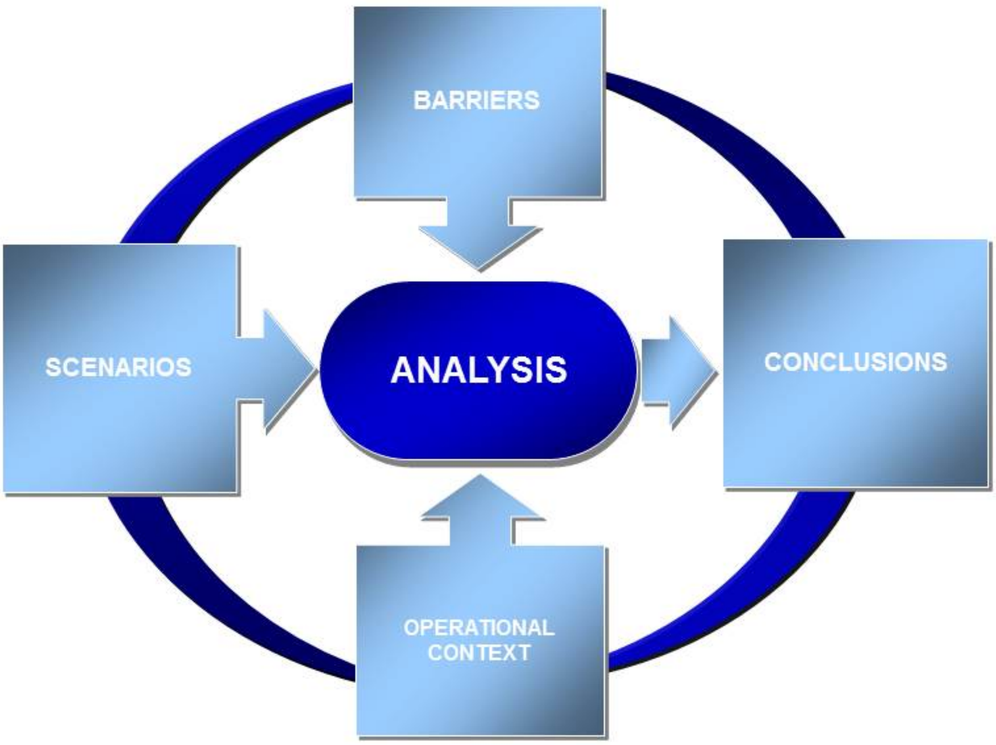
- Mitigation Barriers (MB) 1 – 5 are barriers principally directed to ATC as prevention opportunities
- Mitigation Barriers (MB) 6 - 8 are barriers principally directed to pilots and drivers as prevention opportunities

Barriers mitigating the risk of collision that has been initiated by a SHERC event	**MB1**	**ATCO late direct visual detection**
	MB2	**ATCO late visual detection using remote camera displays**
	MB3	**Aerodrome Surface Movement system including Runway Incursion Monitor (RIM)**
	MB4	**ATC Clearance Conformance Monitoring Alerts and Confliction Detection.** ATCO detection after alert from the use of input and display of the ATC clearances and surveillance data **MB4a: Conformance Monitoring Alerts (CMA)** **MB4b: Conflicting ATC Clearance Alert (CATC)**
	MB5	**Pilot/driver late visual detection**
	MB6	**Sensor Controlled Incursion Projection System (SCIPS)**[3] A system alerting both ATC and the pilot/driver that a lit stop bar has been crossed.
	MB7	**Autonomous Runway Incursion Warning System (ARIWS)** A system which provides autonomous detection of a potential incursion or of the occupancy of an active runway and a direct warning to a flight crew or a vehicle operator. (ICAO Annexe 14)

[3] Used with permission of ADB Airfield Solutions and AGS Airports

		Runway status lights (RWSL) is a type of autonomous runway incursion warning system (ARIWS). The two basic visual components of RWSL are runway entrance lights (RELs) and take-off hold lights (THLs). Either may be installed by itself, but the two components are designed to be complementary to each other. **MB7a: Take Off Hold Lights (THLs**). These are positioned in the runway departure area to provide an indication to pilots and vehicle drivers that the runway is unsafe for take-off. They consist of red unidirectional lights installed in two longitudinal rows of 16 lights each aligned with and offset either side of the runway centreline lighting. **MB7b: Runway Entrance Lights (RELs**). These are installed at taxiway/runway intersections commencing just before runway holding points to provide an indication when it is unsafe to enter the runway.
	MB8	**Airport Moving Maps** **MB8a: 2D with traffic.** Positioned on pilot's Navigational Display this shows airfield layout, position of base aircraft and other aircraft/vehicles including direction of travel. **MB8b: 3D GPS without traffic.** Positioned on pilot's Primary Flight Display. It is similar to automobile GPS but includes track, speed, and height and runway designator.

Chapter 7
Analysis of Barriers in Generic Scenarios



7.1 Prevention Barrier Assessment

The first step of the analysis consists of assessing the potential effectiveness of the prevention barriers in the defined operational scenarios. The high level assessment considers the various operational scenarios and is based on expert judgement.

The barriers are assessed individually, the initial analysis does not consider the interactions or the results of more than one barrier acting in combination. Gap analysis is used to consider best fit options at a later stage.

7.1.1 Assumptions and dependencies

The following assumptions and dependencies are taken for the analysis:

- All barriers are deemed to be operationally available and operated correctly.
- It is assumed that controllers will react correctly to all aural and visual safety nets.
- All barriers are limited by the responsiveness of the players to the signals.
- Deliberate non-conformance is excluded from the analysis.

7.1.2 Colour code used in the Barrier Analysis tables

Red	Barrier that is either ineffective or is not intended for the operational scenario.
Yellow	Barrier that is partially effective for the operational scenario or efficient only under certain conditions.
Green	Barrier that is effective and efficient for the operational scenario.

7.1.3 Key to yellow constraints:

The yellow coding for barrier effectiveness is based on the following conventions:

(1) Prevention possible only if aircraft/vehicle not already on the runway.

(2) Prevention possible subject to daytime/visibility/line of sight.

(3) Prevention possible subject to controller focus of attention on information that shows discrepancy.

(4) Prevention possible subject to pilot situational awareness.

(5) Prevention possible subject to distance travelled on take-off roll before incursion.

(6) Prevention possible for taxying aircraft but not vehicles.

(7) Prevention possible only if landing aircraft is on runway.

Table 1: Effectiveness of Preventative barriers during landing on an occupied runway

	A1a	A1b	B1a	B1b	C1a	C1b	D1a	D1b
PB1: ATCO memory aids							3	
PB2: ATCO direct visual detection	2,3		2	2			2	
PB3: ATCO detection using remote cameras	2,3			2,3			2,3	
PB4: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) level 2	3						3	
PB5: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) level 3/4			3					
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6a**: Conformance Monitoring Alerts (CMA)				1		1		
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6b:** Conflicting ATC Clearance Alert (CATC)								
PB7: Pilot/Driver visual detection	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
PB8: FAROS		4		4		4		4
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9a**: Runway Status Lights Take Off Hold Lights (THLs)								
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9b**: Runway Status Lights Runway Entrance Lights (RELs)		7		7		7		7
PB10: SmartRunway and SmartLanding				6				4
PB11: Airport Moving Maps **PB11a**: 2D with traffic on ND				6				
PB11: Airport Moving Maps **PB11b**: 3D on PFD				6				
PB11: Airport Moving Maps **PB11c**: Pilot Taxi Wizard				5,6				
PB12: 24H stop bars and procedure never to cross lit stop bar								

Table 2: Effectiveness of Preventative barriers during take-off on an occupied runway

	A2a	A2b	B2a	B2b	C2a	C2b	D2a	D2b
PB1: ATCO memory aids								
PB2: ATCO direct visual detection	2,3			2		2		
PB3: ATCO detection using remote cameras	2,3			2,3		2,3		
PB4: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 2	1,3							
PB5: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 3/4	1,3							
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6a**: Conformance Monitoring Alerts (CMA)				1				
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6b:** Conflicting ATC Clearance Alert (CATC)	3,4	1						
PB7: Pilot/Driver visual detection	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
PB8: FAROS								
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9a**: Runway Status Lights Take Off Hold Lights (THLs)		5				5		5
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9b**: Runway Status Lights Runway Entrance Lights (RELs)		1		1		1		1
PB10: SmartRunway and SmartLanding				1,6				
PB11: Airport Moving Maps **PB11a**: 2D with traffic on ND				4	4	4	4	4
PB11: Airport Moving Maps **PB11b**: 3D on PFD								
PB11: Airport Moving Maps **PB11c**: Pilot Taxi Wizard			5,6	5,6				
PB12: 24H stop bars and procedure never to cross lit stop bar								

Table 3: Effectiveness of Preventative barriers during high speed conflict involving intersecting runways

	A3a	A3b	A3c	B3a	B3b	B3c
PB1: ATCO memory aids						
PB2: ATCO direct visual detection	2.3	2,3	2	2	2	2
PB3: ATCO detection using remote cameras	2.3	2.3		2.3	2.3	2,3
PB4: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 2	1,3	1,3				
PB5: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 3/4	1,3	1,3				1.3
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6a**: Conformance Monitoring Alerts (CMA)						
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6b:** Conflicting ATC Clearance Alert (CATC)	3					
PB7: Pilot/Driver visual detection						
PB8: FAROS						
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9a**: Runway Status Lights Take Off Hold Lights (THLs)						
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9b**: Runway Status Lights Runway Entrance Lights (RELs)						
PB10: SmartRunway and SmartLanding				1	1	
PB11: Airport Moving Maps **PB11a**: 2D with traffic on ND	4					
PB11: Airport Moving Maps **PB11b**: 3D on PFD						
PB11: Airport Moving Maps **PB11c**: Pilot Taxi Wizard				5,6	5,6	
PB12: 24H stop bars and procedure never to cross lit stop bar				1	1	

	C3a	C3b	C3c	D3a	D3b	D3c
PB1: ATCO memory aids						
PB2: ATCO direct visual detection						
PB3: ATCO detection using remote cameras						
PB4: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 2						
PB5: Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 3/4						
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection. **PB6a**: Conformance Monitoring Alerts (CMA)						
PB6: ATC Clearance Conformance Monitoring Alerts and Confliction Detection.						

PB6b: Conflicting ATC Clearance Alert (CATC)						
PB7: Pilot/Driver visual detection						
PB8: FAROS						
PB9: Autonomous Runway Incursion Warning System (ARIWS) **PB9a**: Runway Status Lights Take Off Hold Lights (THLs)						
PB9 Autonomous Runway Incursion Warning System (ARIWS) **PB9b**: Runway Status Lights Runway Entrance Lights (RELs)						
PB10: SmartRunway and SmartLanding						
PB11: Airport Moving Maps **PB11a**: 2D with traffic on ND						
PB11: Airport Moving Maps **PB11b**: 3D on PFD						
PB11: Airport Moving Maps **PB11c**: Pilot Taxi Wizard						
PB12: 24H stop bars and procedure never to cross lit stop bar						

7.1.4 Prevention Barrier Effectiveness Tables

In order to organise the results a scoring system was considered; the main purpose is to give a comparison scale and an indication on how effective a barrier can be over the all considered scenarios and not to provide an absolute ranking. One has to bear in mind that in this specific case the barriers are used for the detection of a potential runway incursion, which may then lead to a Sudden High Energy Runway Conflict (SHERC).

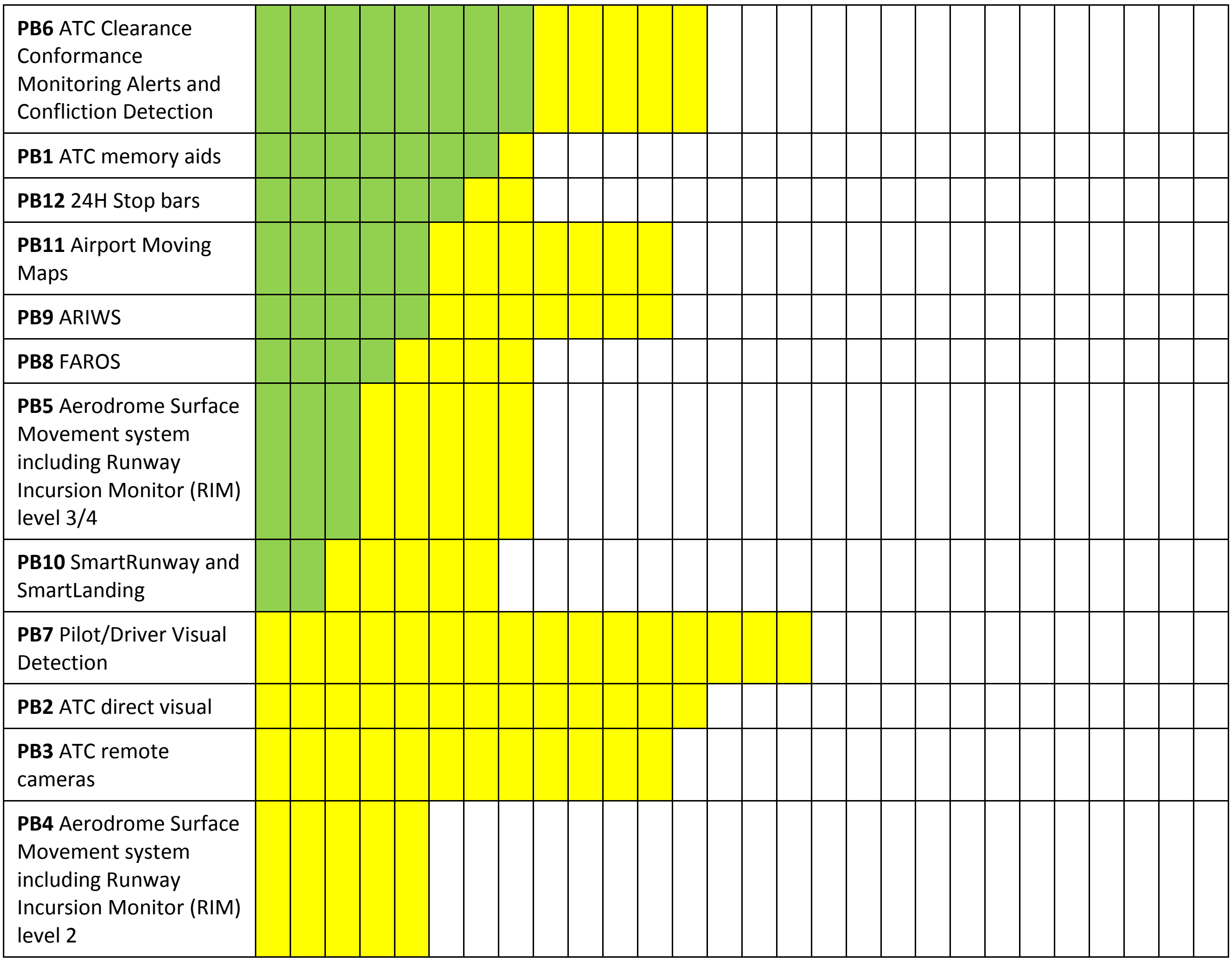
The scoring system utilised to rank the applications is as follows: zero points for an ineffective barrier (red), one point for a partially effective barrier (yellow) and three points for an effective barrier (green).

Table 4: This ranking of Preventing Barriers indicates the barriers that are more effective in the prevention of runway incursions that could lead to a SHERC event.

Barrier	Barrier Description	Score	Effectiveness
PB6	ATC Clearance Conformance Monitoring Alerts and Confliction Detection 6a: CMA 14 6b: CATC 15	**29**	**35 %**
PB1	ATCO memory aids	**22**	**26 %**
PB9	Autonomous Runway Incursion Warning System 9a: THL 18 9b: REL 8 Combined score: 22	**22**	**26 %**
PB11	Airport Moving Maps 11a: 22 11b: 13 Combined score: 22 11c: 5	**22**	**26%**
PB12	24H Stop bars and procedure not to cross illuminated stop bar	**20**	**24 %**
PB7	Pilot/Driver Visual Detection	**16**	**19 %**

PB8	Final Approach Runway Occupancy Signal (FAROS)	**16**	**19 %**
PB5	Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 3/4	**14**	**17 %**
PB2	ATCO direct visual detection	**13**	**15 %**
PB3	ATCO detection with remote cameras	**12**	**14 %**
PB10	SmartRunway and SmartLanding	**11**	**13 %**
PB4	Aerodrome Surface Movement system including Runway Incursion Monitor (RIM) functionality level 2	**5**	**6 %**

Table 5: This table ranks the Preventing Barriers in terms of ability to always prevent potential runway incursions in certain scenarios. The assumption is that the function is applied in a timely and correct manner.



Tables 4 and 5 illustrate clearly the limitations of the available barriers. There is no one barrier available that alone has the potential to prevent more than 35% of runway incursions. Only combinations of preventative barriers, employed correctly, can form a defence that is as low as reasonably practical:

- A combination of the correct use of ATC Memory aids, ATC Clearance Conformance Monitoring Alerts and Confliction Detection and the use of stop bars with procedure never to cross an illuminated bar, is capable of preventing just over half of runway incursions.
- A combination of FAROS, Runway Entrance Lights and Take-Off Hold lights has the potential to prevent a third of runway incursions.
- The introduction of Flight Deck Airport Moving Maps has the potential to prevent a quarter of runway incursions.

- The possibility of either ATC or Pilot/Driver to prevent a runway incursion is limited to about half of all scenarios and is further limited by day/night, visibility and line of sight.
- Very few of runway incursion scenarios that involve the use intersecting runways have any preventative barriers.

7.2 Mitigation Barrier Assessment

The first step of the analysis consists of assessing the potential effectiveness of the mitigation barriers in the defined operational scenarios. The high level assessment considers the various operational scenarios and is based on expert judgement. This judgement includes the likelihood, given the available time, that the barrier could have a substantive effect.

The barriers are assessed individually, the analysis does not consider the interactions or the results of more than one barrier acting in combination. Gap analysis is used to consider best fit options at a later stage.

7.2.1 Assumptions and dependencies

The following assumptions and dependencies are taken for the analysis:

- All barriers are deemed to be operationally available and operated correctly.
- It is assumed that controllers will react correctly to all aural and visual safety nets.
- All barriers are limited by the responsiveness of the players to the signals.
- Deliberate non-conformance is excluded from the analysis.

7.2.2 Colour code used in the Barrier Analysis tables

Red	Barrier that is either ineffective or is not intended for the operational scenario
Yellow	Barrier that is partially effective for the operational scenario or efficient only under certain conditions
Green	Barrier that is effective and efficient for the operational scenario

7.2.3 Key to Yellow constraints:

The yellow coding for barrier effectiveness is based on the following conventions:

(1) Mitigation possible subject to daytime/visibility/line of sight.

(2) Mitigation possible subject to controller focus of attention on information that shows discrepancy.

(3) Mitigation possible subject to pilot situational awareness.

(4) Mitigation possible subject distance travelled on take-off/landing roll before conflict detection.

Table 6: Effectiveness of Mitigation Barriers during a SHERC involving landing on an occupied runway

	A1a	A1b	B1a	B1b	C1a	C1b	D1a	D1b
MB1 - ATCO late direct visual detection	2,3							
MB2 - ATCO late visual detection using remote camera displays								
MB3 - Aerodrome Surface Movement system including Runway Incursion Monitor (RIM)	3	3						
MB4:- ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4a: Conformance Monitoring Alerts (CMA)								
MB4: - ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4b: Conflicting ATC Clearance Alert (CATC)	3	3						
MB5 - Pilot/driver detection	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
MB6 – Sensor Controlled Incursion Projection System								
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7aa**: Runway Status Lights Take Off Hold Lights (THLs)								
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7b**: Runway Status Lights Runway Entrance Lights (RELs)				6		6		6
Airport Moving Maps **MB8a:** 2D with traffic. Positioned on pilot's Nav Display								
MB8b: 3D GPS without traffic. Positioned on pilot's Primary Flight Display.								

Table 7: Effectiveness of Mitigation Barriers during a SHERC involving take-off on an occupied runway

	A2a	A2b	B2a	B2b	C2a	C2b	D2a	D2b
MB1 - ATCO late direct visual detection	2,3							
MB2 - ATCO late visual detection using remote camera displays								
MB3 - Aerodrome Surface Movement system including Runway Incursion Monitor (RIM)								

MB4 -ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4a: Conformance Monitoring Alerts								
MB4 -ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4b: Conflicting ATC Clearance Alerts								
MB5 - Pilot/driver detection	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
MB6 – Sensor Controlled Incursion Projection System								
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7aa**: Runway Status Lights Take Off Hold Lights (THLs)				5		5		5
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7b**: Runway Status Lights Runway Entrance Lights (RELs)		6		6		6		6
Airport Moving Maps **MB8a:** 2D with traffic. Positioned on pilot's Nav Display								
MB8b: 3D GPS without traffic. Positioned on pilot's Primary Flight Display								

Table 8: Effectiveness of Mitigation Barriers during a SHERC event involving intersecting runways

	A3a	A3b	A3c	B3a	B3b	B3c
MB1 - ATCO late direct visual detection	2,3	2,3				
MB2 - ATCO late visual detection using remote camera displays						
MB3 - Aerodrome Surface Movement system including Runway Incursion Monitor (RIM)						
MB4 -ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4a: Conformance Monitoring Alerts						
MB4 -ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4b: Conflicting ATC Clearance Alerts						
MB5 - Pilot/driver detection	2,4	2,4		2,4	2,4	
MB6 – Sensor Controlled Incursion Projection System				5		
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7aa**: Runway Status Lights Take Off Hold Lights (THLs)						
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7b**: Runway Status Lights Runway Entrance Lights (RELs)						
Airport Moving Maps **MB8a:** 2D with traffic. Positioned on pilot's Nav Display						
MB8b: 3D GPS without traffic. Positioned on pilot's Primary Flight Display						

	C3a	C3b	C3c	D3a	D3b	D3c
MB1 - ATCO late direct visual detection						
MB2 - ATCO late visual detection using remote camera displays						
MB3 - Aerodrome Surface Movement system including Runway Incursion Monitor (RIM)						
MB4 -ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4a: Conformance Monitoring Alerts						
MB4 -ATC Clearance Conformance Monitoring Alerts and Confliction Detection. MB4b: Conflicting ATC Clearance Alerts						
MB5 - Pilot/driver detection	2,4	2,4		2,4	2,4	
MB6 – Sensor Controlled Incursion Projection System						
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7aa**: Runway Status Lights Take Off Hold Lights (THLs)						
MB7: Autonomous Runway Incursion Warning System (ARIWS) **MB7b**: Runway Status Lights Runway Entrance Lights (RELs)						
Airport Moving Maps **MB8a:** 2D with traffic. Positioned on pilot's Nav Display this shows airfield layout, position of base aircraft and other aircraft/vehicles including direction of travel.						
MB8b: 3D GPS without traffic. Positioned on pilot's Primary Flight Display						

7.2.4 Mitigation Barrier Effectiveness Tables

In order to organise the results a scoring system was considered; the main purpose is to give a comparison scale and an indication on how effective a barrier can be over the all considered scenarios and not to provide an absolute ranking. One has to bear in mind that in this specific case the barriers are used for the mitigation of a Sudden High Energy Runway conflict that has already commenced.

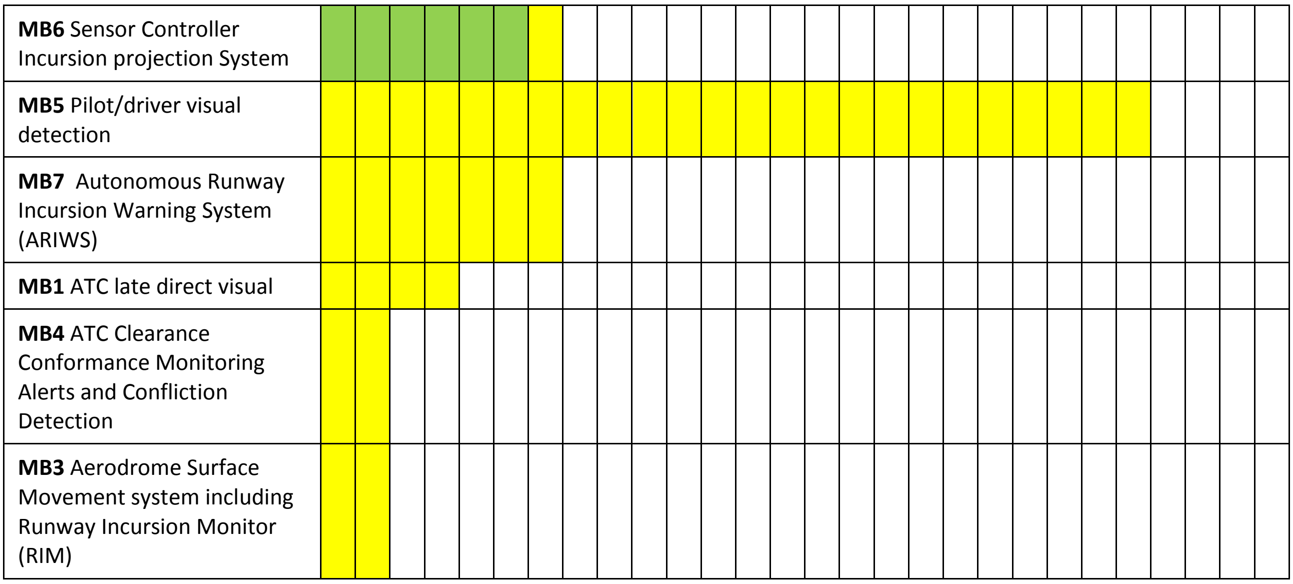
The scoring system utilised to rank the applications is as follows: zero points for an ineffective barrier (red), one point for a partially effective barrier (yellow) and three points for an effective barrier (green).

Table 9: The ranking for the Mitigating Barriers; this ranking indicates which are the barriers that are more effective in the mitigating runway incursions that have commenced and are becoming SHERC event.

Barrier	Barrier Description	Score	Effectiveness
MB5	Pilot/driver detection	**24**	**29 %**
MB6	Sensor Controlled Incursion Projection System	**19**	**23%**
MB7	Autonomous Runway Incursion Warning System (ARIWS) MB7a: Runway Status Lights 7 Take Off Hold Lights (THLs). 3 Combined:7	**7**	**8 %**
MB1	ATCO late direct visual detection	**4**	**5 %**
MB3	Aerodrome Surface Movement system including Runway Incursion Monitor (RIM)	**2**	**2 %**
MB4	ATC Clearance Conformance Monitoring Alerts and Confliction Detection. 4a: CMA 0 4b:CATC 2	**2**	**2 %**

MB2, ATCO late visual detection, was found to be ineffective in mitigation mode. The potential for direct visual mitigation by ATC is itself very little and the added restrictions imposed by the need to be alert to an event on a remote monitor removes that slim chance. MB8, Airport Moving Maps, was found to be ineffective in mitigation mode. This is due to the limitations and positioning of the displays and the point in the timeline that Prevention turns into Mitigation. Airport Moving Maps can, however, be effective in the Prevention stage in some scenarios.

Table 10: This table ranks the Mitigating Barriers in terms of ability to always have a mitigating effect on runway incursions that are in motion and becoming SHERC events.



Tables 9 and 10 illustrate clearly that there is no barrier currently available that is capable of providing effective mitigation in these circumstances. There are only two potential barriers shown to have any significant ability to prevent a collision once a SHERC event has commenced.

The Tables suggests that:

- Situational awareness and alertness resulting in belated visual detection by pilots and airport drivers have the most potential effectiveness. However, visual detection capabilities are limited and is unlikely to be available at all in some scenarios.
- Sensor Controlled Runway Projection System (SCIPS) has the potential to be effective, but only in the clutch of scenarios where an aircraft or vehicle crosses an illuminated stop bar. If the Preventative barrier involving rigorous compliance with the use of stop bars was enabled, the mitigation afforded by SCIPS would be unnecessary.

The ability, therefore, to prevent a runway collision once a SHERC event has been initiated rests almost solely on the situational awareness and vigilance of pilots and airport drivers.

Chapter 8
Analysis of Actual Sudden High Energy Runway Events

The actual safety events described and analysed below are either in the public domain or have been supplied with the permission of the relevant authorities.

In order to dis-identify all stakeholders whilst maintaining the safety lessons, the following editorial actions have been taken:

- No airport, aircraft operator or ANSP is specified.
- The aircraft involved in each event are denoted solely by the aircraft type.
- Controller working positions have been generalised to two terms; TWR meaning the controller in control of the runway, and GMC meaning the controller in charge of the manoeuvring area excluding the active runway (unless otherwise specified).
- Unless necessary to describe the event, no runway or holding point designators are mentioned. In cases where it is necessary e.g. interacting runways, the runway designators have been changed whilst maintaining a general relationship.
- Runway Incursion control/monitoring equipage varies from state to state. To enhance the dis-identification of the airports involves, all such equipage is generically referred to by the term Airport Surface Movement system including Runway Incursion Monitoring (RIM).

A Barrier model is used to show the following in each event:

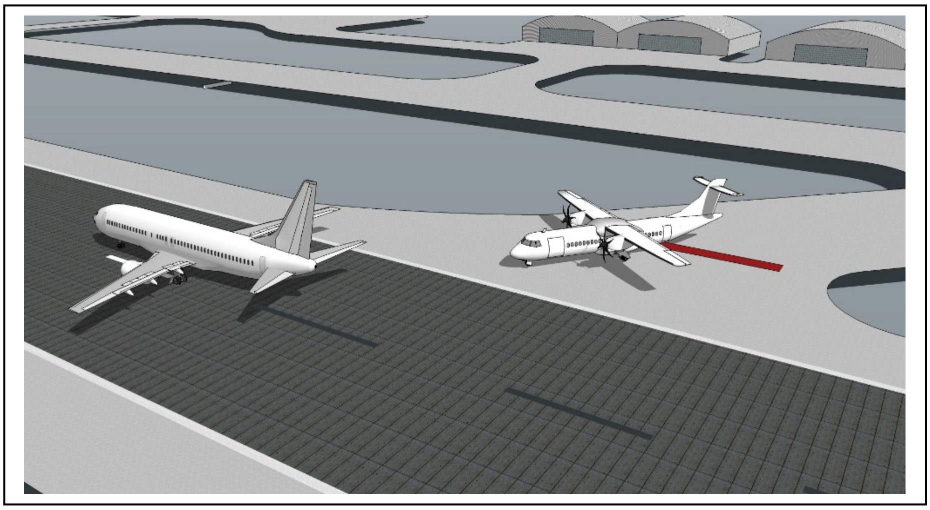
- Actual Recovery Barrier.
- Barriers Breached.
- Remaining Barriers available that could have reduced risk of collision.
- Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision.

8.1 Event 1: Landing as aircraft enters runway at intersection.

Generic Scenario:

Landing on occupied runway	**D1b**	**Aircraft cleared to land, on short final or landing, as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.**

During the hours of darkness an ATR42 was given a conditional line up clearance, but contrary to this clearance, then taxied onto the runway as a B737 was landing on it. The landing aircraft missed the left wingtip of the ATR42 by "a few metres" at high speed.



A conditional clearance is given to the ATR42 "Behind next landing short final, line up 07 behind" The readback is correct. There was no reference, however, to the fact that an A321 will take-off before the next landing.

The A321 takes off. B737 is given clearance to land and ATR42 begins to move onto rwy. When the B737 landed, the ATR42 is 40m from the rwy c/l. The B737 crew saw the ATR42 and deviated to left as soon as possible.

ATC did not see the ATR42 until the pass was taking place. ATR42 crew said they saw the A321 pass them and assumed that was the landing aircraft in the conditional clearance. The holding point that the ATR42 was using was a Rapid Exit Taxiway (RET) for the other end and therefore the view from the flight deck of the ATR42 towards the approach was restricted.

A-SMGCS was available but the RIM function had been disabled due to a perception of there being too many false alerts.

Contributing factors:

Action – Convey incomplete information (conditional clearance)
Decision – Incorrect Plan (to give conditional clearance not relating to next runway movement)
Perception ATC – Did not see aircraft lining up
Perception (Pilot) – Did not see landing aircraft
Perception (pilot) – Misinterpreted visual information (aircraft taking off)
Airport – Line of sight from Rapid Exit Taxiway (RET)
Procedures Airport – Use of RET for departures in mixed mode
Airport Systems – A-SMGCS availability

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

MB1	ATC late direct visual detection
MB5	ATR pilot late visual detection
PBR	Correct use of RTF

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

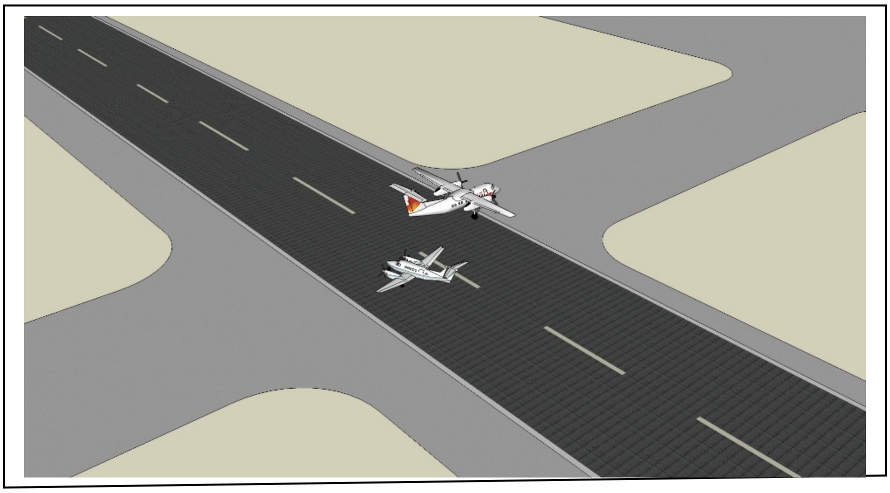
PB12	24H use of illuminated stop bars and robust procedures to never cross a lit stop bar
MB6	Sensor Controlled Incursion Projection System (SCIPS)
MB7b	Runway Entry Lights

8.2 Event 2: Taking-off as aircraft crosses runway without a clearance

Generic Scenario:

Taking-off on occupied runway	**D2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.**

A Bombardier DHC-8 landed on Runway 23. The GMC controller instructed the DHC8 to taxi on Taxiway E and hold short of Runway 27, which needed to be crossed to get to the gate. The hold short instruction was correctly read back. The TWR controller cleared a Beech A100 King Air to take off from Runway 27. Shortly after, the DHC8 entered Runway 27 without stopping. The BE100, which was approaching rotation speed, aborted take-off as soon as it saw the DHC8 on the runway. The BE100 veered to the left of the runway centreline and passed about 10m behind the DHC8. On receipt of take-off clearance, the King Air crew had switched on the landing lights, and without coming to a standstill, the aircraft continued its momentum to begin take-off. At this time, the flight crew of the DHC8, which was some 200m from the hold line of Runway 27, visually scanned the runway. The first officer indicated that the runway was clear to the right of the aircraft, and the captain did the same for the part of the runway to the left.



The GMC and TWR controllers simultaneously observed that the DHC8 was about to cross the runway. The GMC controller ordered the crew to stop, while the TWR controller only transmitted the DHC8 call sign. At about the same time, the DHC8 contacted the apron management service and continued travelling straight ahead, crossing the runway. The BE100 aborted its take-off at 102 knots and braked heavily. The decelerating King Air veered to the left of the runway centreline and passed at 37 knots, about 10m behind the DHC8. A few seconds later, the DHC-8 contacted ground control after being requested to do so by Apron Control.

The DHC8 pilots did not confirm between themselves the ground controller’s instruction to hold short of Runway 27 notwithstanding the first officer’s accurate readback of the instruction. The visual scan conducted by the DHC8 captain was ineffective and did not identify that the BE100 was on Runway 27. During the action of runway crossing, the captain of the DHC8 was talking to Apron Control, contrary to the operator’s SOPs.

Contributing factors:

Pilot Actions – Incorrect action after correct readback
Pilot Actions – CRM issues

Perception (pilot) – Did not see aircraft departing
Non-Conformance – Isolated Team non-conformance – deliberate departure from operator SOPs

Actual Recovery Barrier:

MB5	Pilot visual detection (BE100)

Barriers breached:

PB7	Pilot visual detection (DHC8)

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB9b	Runway Entrance Lights (RELs)
PB11a	Airport Moving Maps 2D
PB12	24H use of illuminated stop bars and robust procedures to never cross a lit stop bar
MB6	Sensor Controlled Incursion Projection System (SCIPS)

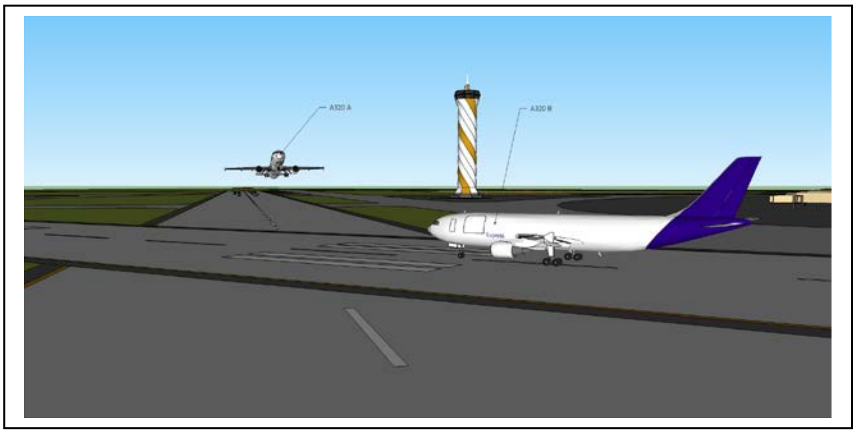
8.3 Event 3 Simultaneous take-off runs on intersecting runways after incorrect ATC clearance

Generic Scenario

High Energy Conflict involving intersecting runways	**A3a**	**Taking-off/Taking-off High Energy conflict on intersecting runways after an incorrect ATC clearance.**

A320(A) reported "ready on reaching" to ATC Aerodrome Control (TWR) when still 700m before the holding point for runway 17. TWR cleared it to line up and wait; and then cleared it for take-off. A320(A) was still 50m short of the holding point at this point. The crew entered runway 17 and initiated their take-off roll.

A320(B) was already waiting in the take-off position on the intersecting runway 29, but TWR decide to change the order of departure to accomodate a change in the traffic situation, which necessitated the departure from runway 17 first. A320(B) received its clearance for take-off 7 seconds before A320(A) began to roll. The crew acknowledged this clearance and immediately initiated their take-off roll. During the take-off roll, the crew of A320(B) noticed A320(A), which was converging from the right on runway 17, and immediately initiated an aborted take-off. At approximately the same time, TWR gave the crew of A320(B) the order to immediately abort their take-off.



The speed of A320(B) at this time was 135 kt. The aircraft came to a standstill at the edge of runway 17. The crew of A320(A) had not noticed the other Airbus and continued their flight to their destination.

Both crews stated they had not noticed the take-off clearance to the other aircraft, although the take-off clearances are clearly audible on both CVRs.

The TWR controller may have been influenced by the fact the Ground Movement Controller (GMC) de-activated the runway blocking indicator on runway 29 (following a crossing aircraft vacating the runway).This indicated to the TWR controller that runway 29 was once more available to him. Immediately afterwards he gave the crew of A320(B) holding on runway 29 take-off clearance.

When this take-off clearance was issued by TWR, the electronic flight strips for the two A320s were in the "Ready for take-off" section on the Flight Data screen. The planned runways are shown for each aircraft but there is no delineation of runway occupancy.

A stage 2 alert was triggered by the RIM function. The blue labels of the two aircraft, A320(A) and A320(B), changed their colour to red and the acoustic alarm sounded. The A320(A) was rolling at a speed of 140 kt and aircraft A320(B) was rolling at 90 kt.

The TWR controller was surprised by the alert and believed in the first instant that it was a *"false alarm with a vehicle"*. In addition, he stated that A320(A) was no longer present in his mental plan at this point in time. He checked whether a vehicle was close to the runways or whether a landing aircraft was on runway 17. He then realized the two aircraft were simultaneously on their take-off rolls. 9 seconds after the RIM alarm he gave the crew of A320(B) the order to “stop immediately”. The crew did not respond to this order as 2 seconds before they had seen the aircraft taking off from runway 17 and had initiated an aborted take-off. When the abort was initiated, A320(B) was rolling at a speed of 135 kt and 550 m before the intersection of runways 17/29. A320(A) was lifting off with a speed of 162 kt.

Contributing factors:

Decision – Incorrect plan prompted by immediate reaction to new input (unblocking of runway call) Blind Spot.
Memory – Forgot previous action (take-off clearance)
Memory – Forgot to carry out visual scan
Equipment – FDP design
Perception (Pilot) – Did not hear take-off clearance to other aircraft
Perception (pilot) – Did not hear take-off clearance to other aircraft
Memory – No recall from working memory
Perception – visual information (RIM)
Perception – auditory information (RIM)
Perception – Did not see conflict developing

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB1	ATCO memory aids for runway occupancy by standardised flight data displays including dedicated runway bays, blocking strips etc
PB2	ATCO direct visual detection
MB1	ATC late direct visual detection. Did not see conflict before RIM alert

Remaining barriers available that could have reduced risk of collision:

x	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

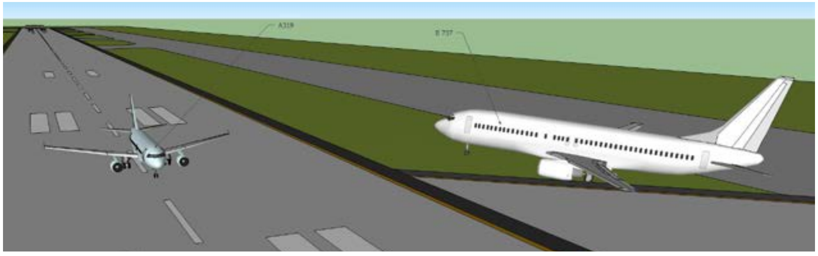
x	Nil

8.4 Event 4: Simultaneous landing and take-off on intersecting runways after incorrect ATC clearance

Generic Scenario

High energy conflict involving intersecting runways	**A3b**	**Taking-off/Landing High Energy conflict on intersecting runways after an incorrect ATC clearance.**

An A319, landing on runway 17 narrowly missed collision with a B737 cleared for take-off on intersecting runway 29. During an approach to runway 15, the A319 asked the TWR controller about the possibility of a switch to runway 17. At this time the aircraft was approximately 3nm from the threshold of runway 15. TWR approved the request but also indicated that an aircraft was on take-off roll on runway 29. Seventeen seconds after the clearance for the runway switch, the A319 received landing clearance for runway 17. The TWR controller was involved for several minutes in an extensive dialogue with a previous flight due a malfunctioning transponder. He broke off this conversation to give a landing clearance to the A319.



In the meantime, in accordance with a previous clearance from the TWR, the next aircraft scheduled to take-off, a Boeing 737, had lined up on runway 29. 1:25 minutes after the A319 had received landing clearance for runway 17, the B737 received take-off clearance from the TWR for runway 29. At this time the A319 was about to touch down on runway 17. Shortly after touching down, the flight crew of the A319 became aware of the B737 on its left, which was at high speed on its take-off roll. The A319 pilot immediately initiated full braking and brought it to a halt about 50 m short of runway 29. The B737 then flew past low over the runway intersection.

Contributing factors:

Memory – Forgot previous action (landing clearance)
Memory – Forgot to carry out visual scan
Equipment – FDP design (strip bay)
Operational Environment – Distraction Job-related

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB1	ATCO memory aids
PB2	ATCO direct visual detection
MB1	ATC late direct visual detection

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

X	Nil

8.5 Event 5: Landing as aircraft suddenly enters runway after misinterpreting its ATC clearance.

Generic Scenario

Landing on suddenly occupied runway	**C1b**	**Aircraft cleared to land, on short final or landing, as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance.**

An A320 partly entered the runway during good ground visibility at the same time as a B737 was about to land in the opposite direction of the same runway and which was not in contact with the TWR controller. The B737 crew saw the A320 incursion as they touched down on the 2200m runway and were able to stop 100m before reaching the A320.

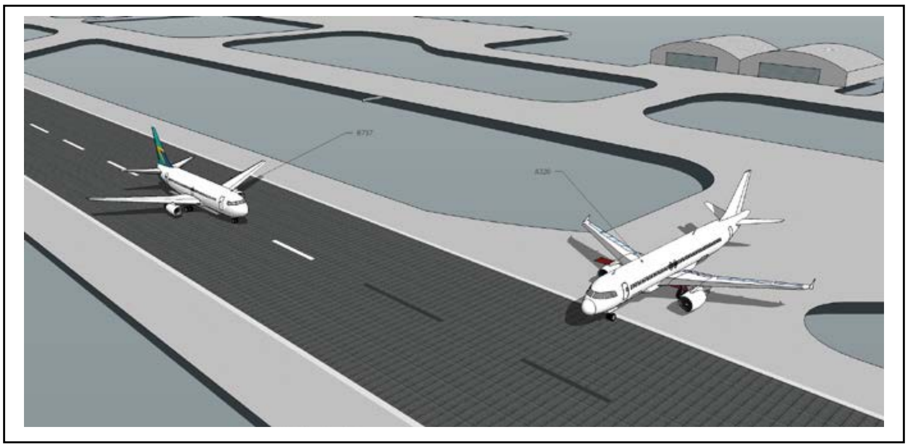
The A320 had been instructed by TWR to “taxi to Holding Point runway 28 via M2”. The A320 pilot requested to taxi via M3 (which routes to the runway threshold) but TWR re-confirmed that the clearance was via taxiway M2 (which routes to an intermediate runway entry point). The TWR controller reported that the A320 had been routed to M2 with the intention that the landing B737 would have the full length of the runway to clear via M3 and then for the A320 to back-track the runway for departure.

The pilot of the A320 assumed that his clearance included entry to the runway in order to backtrack to the Threshold. However, he did not clarify this assumption with TWR and since his aircraft was the only traffic to communicate with TWR during the taxi out, he also assumed that there was no aircraft on approach.

As he taxied across the M2 Holding Point, the Commander of the A320 saw an aircraft on final approach and immediately stopped his aircraft. TWR simultaneously instructed him to hold position. The nose of the A320 was 16m past the Holding Point.

The APP controller, who was not located on the airport, had previously informed the B737 that the runway was clear of traffic and issued a landing clearance subject to the runway being in sight. The B737 pilot reported runway in sight with 3.5 nm to go and the APP controller re-issued the landing clearance and instructed the pilot to contact TWR after landing.

After observing that the A320 had entered the runway and that the B737 was at about 600 feet on final approach, TWR requested APP to instruct the B737 to go around. However, the APP controller did not do so. Realising that the B737 was continuing its approach, TWR instructed it to make a go around but there was no response, the aircraft still being on the APP frequency.



The Commander of the B737 reported that he had been able to see the runway from approximately 1500 feet and had also seen an aircraft taxi out to M2. Then, just after touching down, he reported seeing that the nose of the aircraft was protruding onto the runway. He had then applied maximum manual braking and full thrust reverse and as a result, his aircraft stopped approximately 100m from the A320.

The APP controller did not transfer the arriving aircraft to TWR until after landing, contrary to the prevailing ATC SOP which stated that *"the transfer of control for arriving aircraft shall be performed at 2500 feet"*. The fact that APP and TWR were not co-located meant this SOP was of particular importance. The APP controller did not instruct the B737 to go around when asked to do so.

The RTF phraseology between TWR and the A320 to confirm that the A320 was to hold short of the runway was ineffective. (Note: the holding point does not have a specific name, it is just the holding point at the end of the M2 taxiway)

The TWR controller did not see that the A320 was about to enter the runway in sufficient time to prevent the incursion and did not warn the A320 about the landing traffic.

Contributing factors:

Non Conformance – Failure to transfer B737 from APP to SOP contrary to SOP
Non Conformance – Failure of APP to carry out go around instruction given by TWR
Action – Incomplete RTF between A320 and TWR
Action – Did not inform A320 of B737 landing opposite direction
Decision(Pilot) – Did not question ATC to confirm runway entry assumption
Perception ATC – Did not see aircraft entering runway

Actual Recovery Barrier:

MB5	Pilot visual detection x2

Barriers breached:

PB2	ATC direct visual detection
MB1	ATC direct visual detection
PBP	ATC transfer of communication SOP

Remaining barriers available that could have reduced risk of collision:

	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB12	24H stop bars and robust procedures
MB6	Sensor Controlled Incursion Projection System

8.6 Event 6: Taking-off as aircraft enters runway after mishearing its ATC clearance.

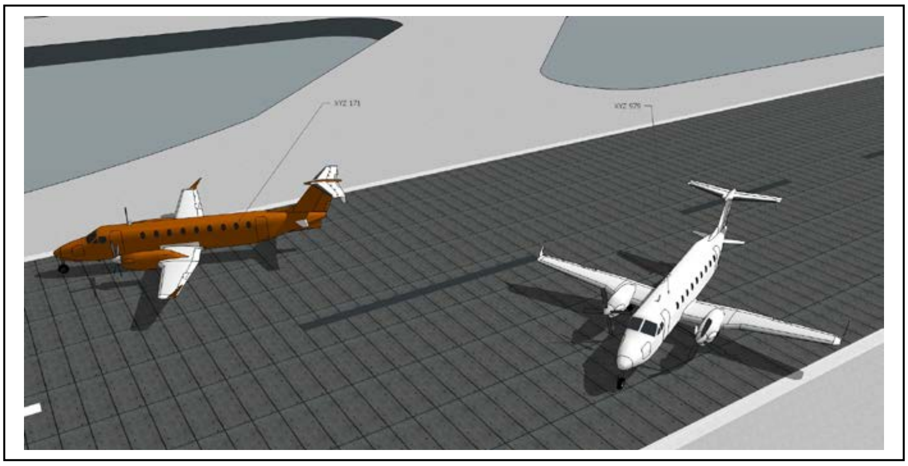
Generic Scenario:

Taking-off on suddenly occupied runway	**C2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance.**

The crew of a Raytheon 1900D aircraft, XYZ171, holding on an angled taxiway mistakenly accepted the take-off clearance for another Raytheon 1900D, XYZ979, that was waiting on the runway and which had a similar call sign. The pilots of both aircraft read back the take-off clearance. The TWR controller heard, but did not react to, the crossed transmissions. The holding aircraft (XYZ171) entered the runway in front of the cleared aircraft (XYZ979), which had commenced its take-off. The pilots of both aircraft took avoiding action and stopped on the runway.

RTF recordings show that XYZ171 at the holding point reported “ready”. The operator designator was clipped and the flight number was unclear. The TWR controller heard a flight call “ready”. He intended to next clear the 1900D waiting on the runway and so, at 0758, he transmitted “(company) 979, runway 24, cleared take off”.

The first officers of both XYZ979 and XYZ171 read back the take-off clearance at the same time. The company was the same and one included “seven one” and the other “seven nine. Both numbers could be heard on the Tower recording. The first officer of XYZ979 said that he heard “seven one” after he had finished his read-back, which he thought was strange, but he did not query it. The TWR controller said that he heard the crossed transmissions, but he did not associate them with either flight.



He had looked away from the runway to assess the weather, and then instructed a light aircraft to change frequency. He did not see XYZ979 start its take-off or XYZ171 move towards the runway. The aerodrome controller’s attention was brought back to the runway when he heard someone transmit “(company) alpha hotel, hold!”

About 10 seconds after XYZ979 began its take-off roll, XYZ171 entered the runway. The first officer of XYZ979 was unsure of the call sign of the infringing aircraft, but could read its registration mark “Alpha Hotel”.

The captain of XYZ979 had already initiated a rejected take-off. He swerved left almost to the runway edge, while the captain of XYZ171 veered his aircraft to the right. Recordings estimate the distance between aircraft to be approximately 8m.

Contributing factors:

Perception (Pilot) – Mishear take-off clearance for another aircraft
Action – Did not Convey information to check which aircraft reported ready
Non Conformance – Did not challenge crossed transmission of take-off clearance

Non-Conformance – Did not monitor active runway movements
Action (Pilot) – Did not challenge reception of crossed transmission of take-off clearance
Procedures Airport – Use of RET for departures
Perception (pilot) – Not see aircraft already lined up and rolling.

Actual Recovery Barrier:

MB5	Pilot visual detection x2

Barriers breached:

MB1	ATC late direct visual detection
PB7	Pilot visual detection
PBR	Correct use of RTF procedures

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

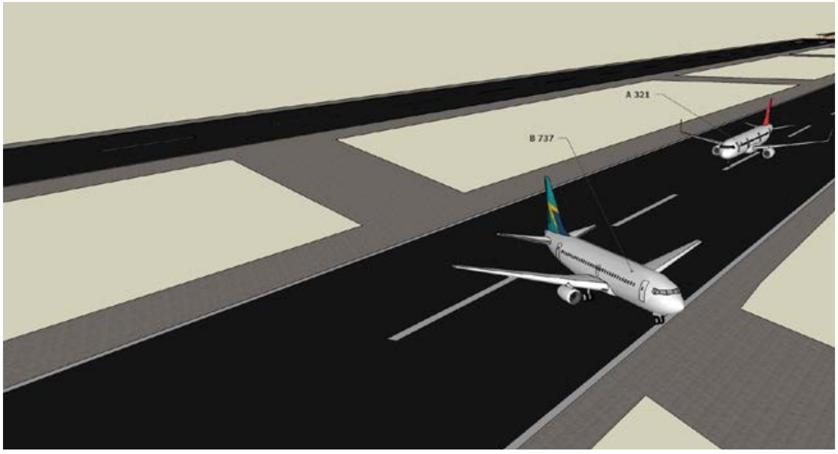
PB12	24H stop bars and robust procedures
MB6	Sensor Controlled Incursion Projection System (SCIPS)
MB7b	Runway Entry Lights
MB7a	Take-off Hold Lights

8.7 Event 7: Incorrect crossing clearance given with aircraft on take-off roll

Generic Scenario

Taking-off on suddenly occupied runway	**A2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.**

B737 taxiing in after landing on 07R with a clearance to cross at an intermediate point on the departure runway 07L, during normal daytime visibility. The pilot of the B737 did not notice an A321 accelerating along the same runway on its take-off roll. However, the A321 crew saw the conflict and made a high speed rejected take off as the B737 continued across the runway ahead.



Both aircraft had been operating in accordance with their respective ATC clearances. The A321 had been cleared for take-off immediately before the B737 had checked in on the same frequency with a clearance from GMC to hold short of the runway. A crossing clearance was then given and repeated because of another transmission from a non-involved aircraft over the first attempt. Although the first transmission of the crossing clearance was not heard by the A321 crew, it had coincided with the completion of standard flight crew calls related to their take-off. The repeat of the clearance was heard and, as its significance was being assimilated, the B737 was seen entering the runway at what was perceived as a very rapid speed and initiation of the rejected take-off, shortly after the standard airspeed crosscheck at 100 knots had been completed, followed, accompanied by the call 'Stopping' on frequency.

The B737 had been taxiing at an average speed of 33 knots between clearing runway 07R after landing and entering runway 07L. When the B737 entered the runway, the A321 was 800m away from the crossing point. By the time the B737 vacated the runway, the A321 was, as a result of the rejected take-off action, 400m from the crossing point.

The B737 commander recollected looking left as his aircraft was about to enter runway 07L, but he had not seen the A321 and since it was evident that the position of his aircraft at that time would have allowed him to see the other aircraft, this reported check was not effective.

The TWR controller stated that he remembered giving a line-up clearance to the A321 but did not remember giving the subsequent take-off clearance. His recollection was that he had given the inbound aircraft priority across the runway. He had placed the Flight Progress Strip (FPS) for the B737 in the corresponding position and that when he had seen the A321 coming into view and accelerating, his initial thought was that it had begun take off without clearance. The controller did not remember seeing the Runway Incursion Monitor (RIM) activate as the conflict occurred.

Contributing factors:

Memory – Forgot previous action (take-off clearance)
Action – Did not select/position strips in the intended manner
Perception – Did not see aircraft commence take-off roll.
Perception (B737 Pilot) – Did not see aircraft on take-off

Actual Recovery Barrier:

MB5	Pilot visual detection x2

Barriers breached:

PB1	ATCO memory aids
PB7	Pilot detection (B737)
MB1	ATC late direct visual detection
MB3	ATCO detection using Aerodrome Surface Movement system Inc. RIM

Remaining barriers available that could have reduced risk of collision:

	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB9b	Runway Entry Lights

8.8 Event 8: Simultaneous landing and take-off from intersecting runways after incorrect ATC clearance.

Generic Scenario

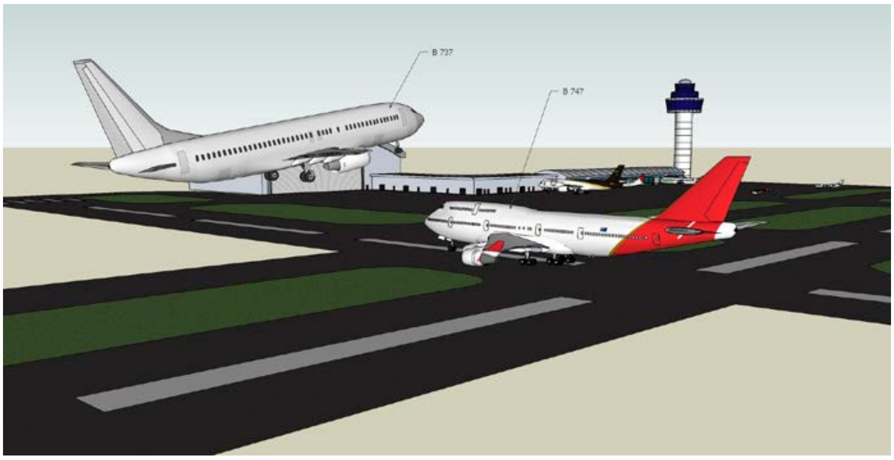
High energy conflict involving intersecting runways	**A3b**	**Taking-off/Landing High Energy conflict on intersecting runways after an incorrect ATC clearance.**

A B737 executed an early rotation during a night take-off when a B747 was observed on a landing roll on an intersecting runway.

At the time of the incident, the North and South TWR roles were combined on the South position. The South TWR controller was responsible for aircraft landing and departing runway 15R and departing runway 28L. A second controller (TWR2) was still responsible for aircraft departing runway 23L, which was to the south of both 28L and 15R. Aircraft departing from runway 15R entered TWR2's airspace, South TWR was required to coordinate with TWR2 for the release of those flights. South TWR verbally coordinated the release of two departure aircraft from 15R that he intended to depart before the B747 landed.

The flight crew of the B747 made initial contact with South TWR at 9DME for 15R. The South TWR cleared the B747 to land with the proviso that "traffic will depart ahead of your arrival." The South TWR controller then instructed the B737 to position and wait on 28L with traffic information on landing, departing and crossing traffic. The crew replied that they needed about two minutes.

The crew of the B737 advised that they were ready. The South TWR reported that he carried out a visual check and scanned the electronic strip display. He did not see the B747 short final to 15R either visually or on from electronic strip display. The South TWR controller cleared the B737 for take-off 28L.



The TWR2 controller said he saw the B747 on landing roll on runway 15R. Initially he thought that it would turn off before the 28L intersection. When he realised that this was not the case, he alerted the South TWR controller. The South TWR controller transmitted, "stop, stop, and stop".

On receipt of the call from ATC, the Captain of the B737 reported that at 110 kts he did not feel able to abort and stop prior to the intersection (around 110-120 knots), so he decided to continue accelerating towards the B747 and if needed, attempt to rotate over him. The B747 continued encroaching onto his runway, and it became clear that he would have to rotate early to clear it. By the time he rotated, the B747 was fully on the runway. He began the rotation 10kts earlier than the planned 140kts. The B737 was at approximately 150ft when it passed over the B747.

Contributing factors:

Decision – Incorrect plan prompted by immediate reaction to new input (ready for take-off)

Memory – Forgot previous action (landing clearance to B747)
Perception – Did not see aircraft landing
Perception – Did not see conflict on strip display

Actual Recovery Barrier:

MB1	ATCO late direct visual detection

Barriers breached:

PB1	ATCO memory aids
PB2	ATC direct visual detection

Remaining barriers available that could have reduced risk of collision:

MB5	Pilot visual detection

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

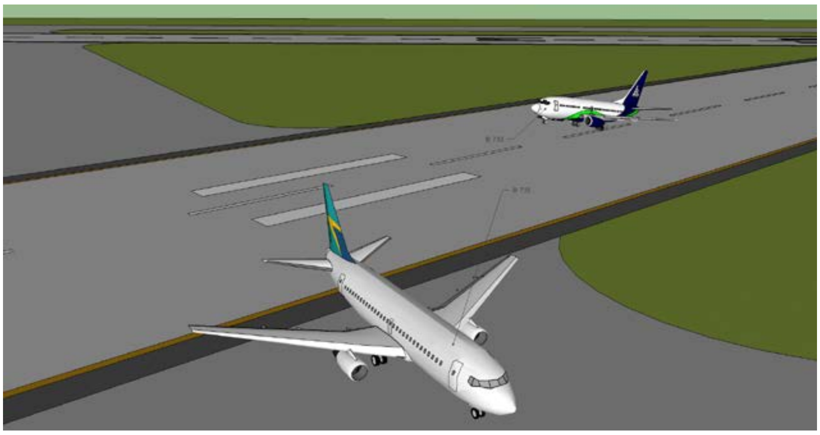
PB11a	Airport Moving Maps

8.9 Event 9: Incorrect crossing clearance given with aircraft on take-off roll

Generic Scenario

Taking-off on suddenly occupied runway	**A2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.**

A B735 that was taxying after landing and a B733 that was taking-off almost collided in normal day visibility when the just-landed aircraft crossed the runway on which the departing aircraft was taking-off. The latter was able to get airborne just in time to pass over the taxyiing aircraft but returned to land because a suspected, and subsequently confirmed, tail strike sustained during the avoidance manoeuvre.



The B733 had been cleared for take-off from runway 19L. Some 30 seconds later, the same controller cleared the B735, which had landed on runway 19R and taken a Rapid Exit Taxiway, to cross the same runway without stopping. The crew of both aircraft recognised the high risk of collision and took evasive action. The Captain of the taxiing aircraft increased thrust in an attempt to clear the runway more quickly. The Captain of the departing aircraft rotated more rapidly and earlier than planned in order to just fly over the crossing aircraft.

5 minutes prior to the event, the TWR and GMC positions had been combined. However, it then quickly became clear that it was becoming too busy to continue with the combined position and the just-relieved GMC controller, who was still present, moved back to his workstation to de-combine the positions. However, the incident happened before this could take effect.

The controller's workload was very high. An ill-tempered comment to a taxying aircraft that was causing a problem was symptomatic. The controller agreed that he did not scan runway 19L when he cleared the B735 to cross. There were four control personnel in the VCR, all stated that they did not see the incident.

12 seconds after closest point, the pilot of the airborne B733 attempted to contact TWR but received no response. Two other pilots who attempted to call TWR also received no response. TWR instructed the pilot of the B733 to contact departure control. The pilot asked if ATC had seen a (company) airplane cross in front him on take-off roll. TWR said he had not. The pilot responded that someone cleared the (company) to cross runway 19L after he had been cleared for take-off. TWR asked the pilot to confirm his location during the incident. The pilot responded that he had been on take-off roll on 19L and "we just missed him by a little bit."

Contributing factors:

Decision – Incorrect Plan in response to new input. Blind Spot.
Memory – Forgot to scan runway before clearance
Perception – Did not see conflict visually

Perception – Did not see conflict on strip display
Personal Factors – Excessive workload.
ATC Org – Position Splitting/Combining

Actual Recovery Barrier:

MB5	Pilot visual detection x2

Barriers breached:

PB1	ATCO memory aids
PB2	ATC direct visual detection
MB1	ATC late direct visual detection

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB9b	Runway Entry Lights

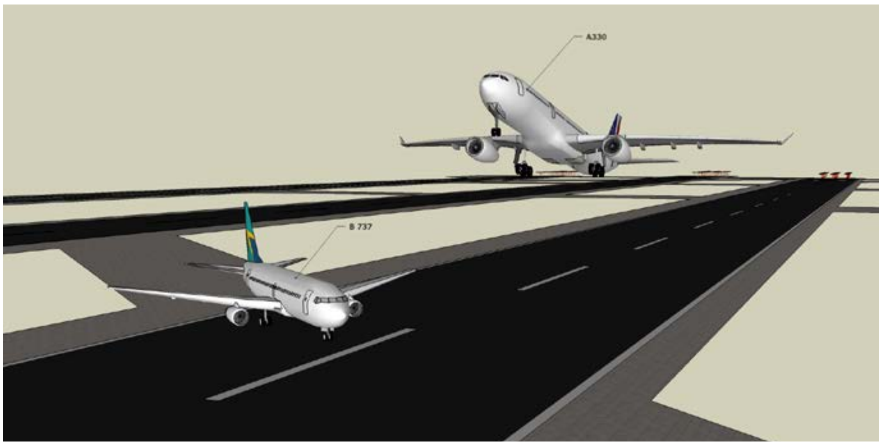
8.10 Event 10: Taking-off as aircraft crosses runway after poor CRM and incorrect execution of the plan.

Generic Scenario

Taking-off on suddenly occupied runway	**D2b**	Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.

A B737, in normal ground visibility at night, failed to hold clear of runway 35R during taxi in after landing on runway 35C and passed almost directly underneath an A330 which had just become airborne with an estimated vertical clearance of 300 - 400 feet between the two aircraft.

TWR had instructed the B737 to hold short of the runway and this had been correctly read back and subsequently verified a second time. After the captain acknowledged the hold short clearance, he took control of the airplane and called for the "After Landing" checklist. This required the FO to direct his attention inside the cockpit to complete the checklist items. The FO acknowledged the second hold short clearance. The crew then shut down the right engine. They also stated that they had not heard the A330 being given take-off clearance on the same frequency.



TWR received an aural and visual alert from the RIM when the B737 crossed the taxiway hold short lines, and proceeded across the runway edge line onto runway 35R. The RIM activated 6 seconds before the B737 crossed the runway edge but the alerts were not in sufficient time to facilitate a useful response from the TWR controller.

After the event, both flight crew members of the B737 stated that they looked for but could not see the taxiway hold short markings or lights (which are located 280m beyond the runway 35C runway edge markings and 77m short of the runway 35R runway edge markings). The first officer stated that the brightness of the green taxiway centerline lights and a developing haze obscured his view of the taxiway markings, lighting, and signage. The captain stated that he looked down at his airport diagram. He stated that he expected the hold short lines would be perpendicular to runway 35R.

The taxiway had enhanced hold short lines, a lit centre-line and elevated runway guard lights at the holding point concerned.

The A330 flight crew subsequently advised that they had not seen the B737, probably because they were rotating.

Contributing factors:

Operational Environment (Pilot) – Distraction Job Related
Perception (Pilot) – Did not see hold short lines
Perception (pilot) – Did not see runway guard lights

Perception (pilot) – Did not see runway edge lights
Perception (pilot) – Did not see aircraft on take-off roll
Pilot Actions – CRM issues
Pilot Actions – incorrect action to readback

Actual Recovery Barrier:

X – Providence

Barriers breached:

PB7	Pilot visual detection of runway guard lights
MB5	Pilot visual detection of departing aircraft
MB3	ATC action after RIM alert

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB12	24H stop bars and robust procedures
PB9b	Runway Entry Lights
MB6	SCIPS

8.11 Event 11: Incorrect take-off clearance given with previous landing aircraft still on runway.

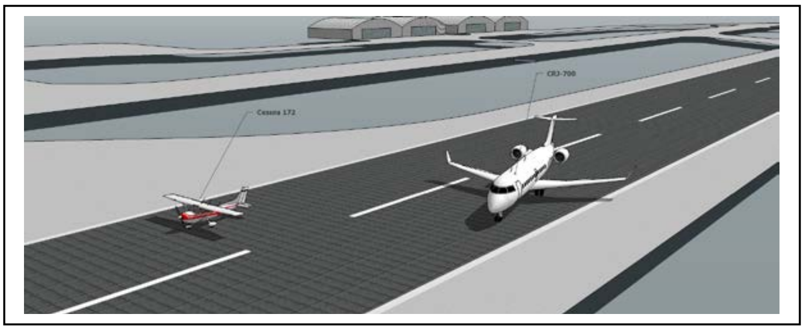
Generic Scenario

Taking-off on suddenly occupied runway	**A2a**	**Runway entry by aircraft/vehicle in accordance with clearance. Shortly after, ATC incorrectly clear an aircraft that is lined up to take-off.**

A CRJ700 made a high speed rejected take-off upon seeing a light aircraft on the runway ahead at night. By veering to the left around it whilst decelerating, a collision was avoided.

The Cessna 172 had just landed on the same runway and, after landing had been instructed to clear right at the first exit, located at 450m from the landing threshold. Half a minute later, the controller cleared the CRJ700 for take-off and shortly after that, the C172 advised that it was still on the runway having missed the turn off and asked to exit next right. TWR responded with “no delay…turn immediately” which was acknowledged. TWR did not instruct the CRJ700 to stop its take-off or give traffic information.

The pilot of the C172 reported that about 3 or 4 seconds after been instructed to turn immediately, the regional jet had passed to his left. He stated that he had not been aware of the issue of a take-off clearance given to the other aircraft.



The CRJ700 crew reported that at a speed of about 110kts, they had heard the light aircraft say he had missed his turn off and the First Officer had then seen a white aircraft tail light to the right of the centreline ahead and immediately called “Abort, Abort”. They steered to the left with maximum braking and they had subsequently passed to the left of the Cessna with an estimated 3m clearance at a speed of approximately 40Kts.

The controller on the TWR frequency had been certified in the TWR position a month prior to the incident. The Investigation noted that of his 80 hours training time for that certification, less than one hour was recorded as being at night. He did receive a daytime airfield tour during his training in order to orient himself with the airport layout, but he had never been out on the airport movement area at night.

He stated that he had scanned the runway before issuing the take-off clearance to the CRJ. He did not recall actually seeing the Cessna clear the runway but assumed that it vacated as he could not see it. When asked what he had intended with his instruction to the Cessna to “turn immediately”, he responded that he had “wanted the aircraft to get off the runway even if it had to turn into the grass” Asked why he did not say anything to the CRJ during the event, he stated that he saw the CRJ decelerating on the runway and was trained not make transmissions to pilots in a critical phase of flight. Asked what caused the incident, the controller stated that he just "lost the Cessna in the lights."

The airport does not have ground surveillance radar.

Contributing factors:

Perception – Misperceive visual information

Decision – Incorrect plan to give take-off clearance without positive evidence of rwy clearance
Perception – Did not see C172 during scan
Training – Lack of completeness
Training – Task familiarity

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB2	ATC direct visual detection
PBP	Correct use of ATC procedures re- runway vacation
MB1	ATC late direct visual detection

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

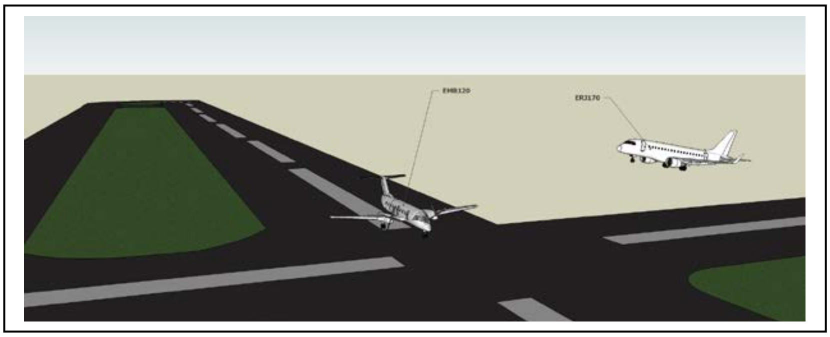
PB9a	Take-Off Hold Lights

8.12 Event 12: Simultaneous landing and take-off on intersecting runways after incorrect ATC clearance.

Generic Scenario

High energy conflict involving intersecting runways	**A3b**	**Taking-off/Landing High Energy conflict on intersecting runways after an incorrect ATC clearance.**

An Embraer 170 taking-off from runway 02 was obliged to closely overfly an Embraer 120 which had just landed on intersecting runway 29 and had stopped on the intersection. Daylight visibility was good. The intersection where the conflict occurred was approximately 1860 m from the landing runway threshold and approximately 1580 m from the take-off runway threshold. The TWR controller expected the E120 to vacate the runway prior to it reaching the 02/29 intersection. His plan, however, was inadequate.



Having cleared the arriving aircraft to land on runway 29, the TWR controller responsible for both runways had then cleared the other aircraft to take-off from runway 02 one second before the arriving aircraft crossed the 29 threshold. The RIM system alerted 28 seconds after this clearance and 15 seconds prior to the eventual conflict at the intersection of the two runways. 4 seconds after the alert, the TWR controller instructed the aircraft on landing roll to *"hold, hold, hold"* and it had come to a stop exactly on the intersection ahead of the departing aircraft.

The E170 pilot observed the E120 as they were rotating. It is estimated that the E170 was only climbing through about 100 feet when it overflew the E120.

Contributing factors:

Decision – Plan inadequate
Perception – Did not see conflict out of the window
Action – Conveyed no information to landing aircraft re departure
Action – Conveyed insufficient avoiding action information to landing aircraft

Actual Recovery Barrier:

MB5	Late pilot visual detection (not tested)

Barriers breached:

PB1	ATC direct visual detection
MB3	ATCO detection after RIM alert
MB5	Late pilot detection (landing aircraft)

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

X	Nil

8.13 Event 13: Incorrect line-up clearance given from intersection with aircraft on take-off roll from the full length.

Generic Scenario

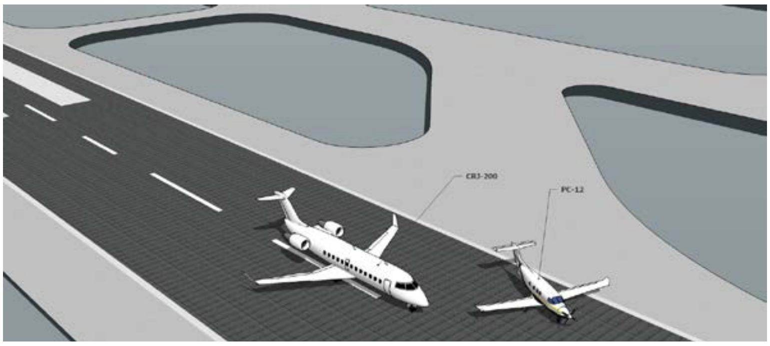
Taking-off on suddenly occupied runway	**A2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.**

A Bombardier CRJ 200 in normal daylight visibility observed a small aircraft enter the runway ahead of them whilst at high speed on their full length take-off roll but were able to make an emergency stop on the centerline just clear of the other aircraft. The other aircraft, a Pilatus PC12, moved to the side of the runway when its pilot realised the situation.

ATC procedures require the GMC controller to verbally notify the TWR controller anytime an aircraft is taxied for a departure to a location other than the full length of the runway. Additionally, the flight progress strip for the aircraft departing from the intersection must be annotated with the intersection taxiway identifier and circled in red. Both of these procedures were completed; however, the TWR reported that he did not hear the GMC controller.

TWR cleared the CRJ200 for take-off 3 seconds later, TWR directed the PC12 to taxi into position and hold on the runway, which was acknowledged by the pilot. The TWR controller stated that he did not visually check the position of the PC12 nor did he scan the flight progress strip that was annotated as an intersection departure. Moreover, the TWR controller stated that he did not scan the runway to ensure the runway was clear.

The PC12 pilot was not aware, either by R/T monitoring or visually, of the take-off clearance given to the CRJ 200 prior to runway entry.



As the PC12 entered the runway, the RIM system activated with an aural alert: “Warning, Runway (number) occupied”. TWR cancelled the take-off clearance by transmitting “uhm cancel take-off clearance uhm (company)”. The CRJ200 crew responded that they were “rejecting”.

The pilots of the CRJ200, reported that as they started the take-off roll both pilots saw the PC12 approaching the runway from the left side. As they continued to accelerate to approximately 85 knots, they noticed that the PC12 did not appear to be slowing down to hold short of the runway. When it became apparent that the PC12 was not going to stop and hold short of the runway, they initiated a rejected take-off. According to the pilot in command, they came to a complete stop on the centerline of runway approximately 1 m from the PC12. The pilots of the CRJ200 agreed that the PC12 stayed to the left of the centerline which prevented a collision.

It was noted the RIM equipment had provided an alert which was too late to be effective and that the controller’s own action to rescind the take-off clearance was also too late and lacked urgency.

Contributing factors:

Perception – Did not hear verbal coordination
Perception – Did not see runway marking on the PC12 strip
Perception – Did not see PC12 position
Non Conformance – did not monitor runway movements
Perception (pilot) – PC12 pilot did not see aircraft on rwy before entering rwy
Perception (pilot) – PC12 pilot did not hear take-off clearance given to other aircraft

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB1	ATC Memory aids
PB2	ATC visual detection
PB7	Pilot direct visual detection (PC12)

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB12	24H stop bars and procedures
PB9b	Runway Entrance Lights
MB6	Sensor Controlled Incursion Projection System

8.14 Event 14: Taking-off as vehicle entered runway without an ATC clearance

Generic Scenario

Taking-off on occupied runway	**D2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due poor CRM and/or incorrect execution of the plan.**

A PA31 was cleared for take-off in normal visibility from runway 06, becoming airborne just before overflying a runway inspection vehicle which had entered runway 06 contrary to its clearance.

The aircraft was estimated to have been about 30 feet agl when it passed over the 6-feet high vehicle. As the taking-off aircraft accelerated, the pilot saw that a vehicle on his right was moving along runway 33 towards the intersection and had become concerned that it may continue onto the active runway. He had concluded that rejecting the take-off would probably lead to a ground collision and therefore elected to continue and achieve a rotation prior to the intersection so as to overfly the vehicle if it did not stop.

The vehicle driver had been inspecting the T-VASIS on runway 33 and then drove northwest carrying out a surface and lighting inspection. This had been conditional on remaining short of runway 06. This had been correctly read back approximately two minutes prior to the incursion. About a minute after accepting this clearance, the vehicle driver was found to have taken a mobile phone call which had still been in progress at the time of the incursion. Although the vehicle driver subsequently advised that he had been aware that an aircraft was about to depart from runway 06 prior to taking the phone call, he believed that his situational awareness had then been compromised by the distraction of the telephone call.

The Airside Driving Handbook issued by the airport operator stipulated that *"mobile telephones were not to be used while operating a mobile vehicle airside"*.

Contributing factors:

Non Conformance (driver) - Driver using mobile phone contrary to Airside Driving Handbook
Memory (driver)– No/Incorrect recall from working memory due distraction
Operational environment (driver) – Distraction non-job related
Memory – ATC forgot to monitor runway movements

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB8	Driver visual detection

PBP	Airside Driving SOPs

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

X	Nil

8.15 Event 15: Landing after vehicle has entered runway following misinterpretation of its ATC clearance.

Generic Scenario

Landing on suddenly occupied runway	**C1b**	**Aircraft cleared to land, on short final or landing, as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance.**

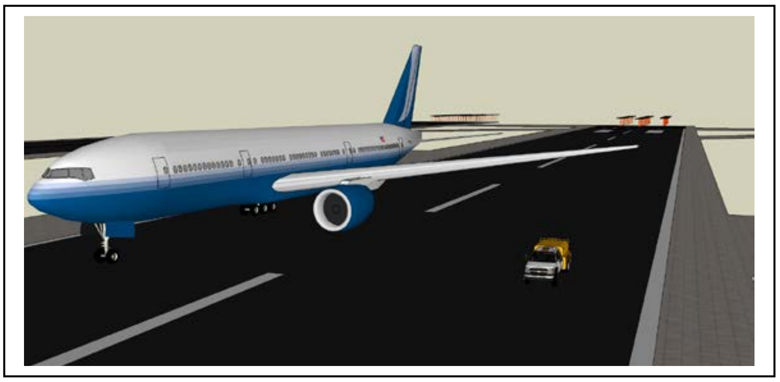
A Boeing 777 crew which had just landed saw a vehicle ahead and were able to manoeuvre to avoid it although the aircraft's left wing still passed over the moving vehicle.

The vehicle involved was being operated by a runway maintenance company contracted by the aerodrome operator and at the time had been occupied by a driver who held an appropriate permit but the R/T was being operated by an assistant who did not have an Airside Driving Permit (ADP).

The vehicle was instructed by the controller responsible for the movement of ground vehicles to proceed to a designated holding point and "wait for three or four minutes". The TWR controller responsible for issuing aircraft clearances to land verified visually that the vehicle had arrived at the holding point.

About a minute later, a third controller "*in a supervisory role*", who was unaware of the earlier clearance issued by the GMC controller but aware that the vehicle needed access to the runway to remove a bird carcass, instructed the vehicle to "*proceed for runway (X), prepare to enter runway (X) to pick up a bird carcass*". This transmission was answered by the vehicle driver's assistant with the words "*Roger Tower runway (X) thank you*" and this read back was not challenged.

Following this clearance, the vehicle entered the runway, crossing the red stop bar in accordance with prevailing practice at the time which only required it to be switched off when a corresponding aircraft clearance was issued.



Eight seconds after the incursion occurred, the TWR controller issued a landing clearance to the B777 as it was passing 1.5nm from the threshold. This controller advised that he had visually scanned the runway prior to issuing this clearance. A vertical beam in the VCR window coincided with the TWR controller's view of the area of runway where the vehicle was present. The TWR controller agreed, however, that he had not checked the A-SMGCS. The incursion generated both a visual and an aural warning of the incorrect presence of the vehicle on the runway. Unfortunately, it was normal practice not to refer to the A-SMGCS display during daytime when the visibility was good.

Both B777 pilots reported not having seen the vehicle until after touch down when the aircraft was decelerating through approximately 100 knots. As a result of the sighting, well to the left of the runway centreline, the aircraft commander had taken control, substituted manual braking for autobrake to increase the deceleration rate and made a deviation to the right to ensure clearance so that only the outer left wing passed over the vehicle.

Contributing factors:

Action (Sup Controller) - Convey unclear information (conditional clearance)
Action (Sup Controller) – Did not convey his input to controller in charge of vehicle movement
Non Conformance – Person operating RTF in vehicle did not have a permit
Non Conformance – Driver of vehicle that had Airfield Driving Permit was not monitoring/checking unqualified person
Operational Environment – Visual impairment from VCR
Airport Procedures – Allowed vehicles to cross lit stop bars
Airport Procedures – Vehicles on runway not in contact with executive controller for that runway

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB2	ATC direct visual detection
PB7	Driver visual detection
MB1	ATCO late direct visual detection
MB3	ATCO detection using Aerodrome Surface Movement system Inc. RIM
MB5	Driver visual detection
PBP	Airport Airside Driving Procedures
PBR	ATC RTF Procedures

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB12	24H Stop bars and robust procedures for vehicles never to cross a lit stop
PB8	FAROS
MB6	Sensor Controlled Incursion Projection System
PBP	Runway vehicle procedures: One runway , One frequency, One controller

8.16 Event 16: Taking-off as vehicle enters the runway after an incorrect ATC clearance.

Generic Scenario

Taking-off on suddenly occupied runway	**A2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.**

An SR22 aircraft was given take-off clearance runway 05 by TWR. A Bird Scaring Vehicle entered the same runway from the intersecting RWY 32 and proceeded along the RWY 05. Clearance to enter RWY 05/23 and to proceed along the RWY had been issued by the Vehicle Movement Controller without coordination with the TWR controller, contrary to procedures.

One of the contributing factor was the presence of visitors in the Tower VCR and on the balcony to view the arrival of a new A330. They produced quite a distraction and created obstacles by standing in the field of vision of Vehicle Movement controller. According to the SR22 pilot's statement, he saw the vehicle on the RWY and at this time he reached V_1. He decided not to abort take-off, but to continue. He got airborne approximately 150-200 m before the vehicle and passed 7 -15 m above it.

The taxi distance from the General Aviation Park to the runway holding point was very short and the pilot reported ready on reaching to TWR. The Vehicle Movement controller was not aware of the SR22 and did not hear communication of the TWR controller with it (due to increased noise) and did not see the aircraft entering RWY 05 (due to view by visitors) and also the fact, that the aircraft was very small – so assumed that there is no traffic on the RWY 05/23. Clearance by the TWR for take-off was issued at the same time when the Vehicle Movement controller cleared the vehicle to enter the RWY. (Neither controller heard each other's communication).

Vehicles on the runway are not in contact with the TWR controller responsible for that runway.

Contributing factors:

Non Conformance (VMC)– cleared vehicle to enter rwy without coordination, contrary to procedures
Airfield Procedures – VMC only talks to vehicles and has no knowledge of aircraft movement
Perception (VMC) – did not hear TWR issuing line up and take-off clearances
Perception (VMC) – did not see aircraft on runway
Decision (VMC) – Incorrect plan. Aircraft was small and short taxi – Assumption of no traffic
Operational Environment – Visual impairment from VCR (people)
Operational Environment – Distraction – Noise from people in VCR
Airport Procedures – Vehicles on runway not in contact with executive controller for that runway

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PBP	ATC procedures
PB2	ATC direct visual detection
PB7	Driver direct visual detection
MB1	ATC late direct visual detection (VMC)

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PBP	Runway Vehicle Procedure – One runway, One frequency, One controller

8.17 Event 17: Taking-off with a vehicle entering the runway after mishearing its ATC clearance.

Generic Scenario

Taking-off on suddenly occupied runway	**C2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance**.

During night-time operations, an Airport Vehicle reported at Runway 09L at Taxiway E and requested clearance onto the runway. The TWR controller cleared the vehicle onto Runway 27L (not Runway 09L). The vehicle driver read back that he was proceeding on Runway 09L and the TWR controller replied "Roger, proceed on Runway 27L". The vehicle duly entered Runway 09L/27R. The controller subsequently cleared an A321 for take-off on Runway 27R. The RIM function alerted at which point the controller cancelled the A321's take-off clearance. The A321's ground speed indicated 120 knots at the time of abort. The A321 came to a stop 155m from the vehicle.

Contributing factors:

Perception (TWR) – mishear vehicle position report
Perception (driver) – mishear ATC clearance (expectation bias)
Perception (TWR) – mishear incorrect read back
Perception (TWR) – did not see vehicle
Perception (Driver) – did not see aircraft
Perception (Pilot) – did not see vehicle on runway

Actual Recovery Barrier:

MB3	ATCO detection using Aerodrome Surface Movement System e.g. RIM

Barriers breached:

PB2	ATC direct visual detection
MB1	ATC late direct visual detection
MB5	Late driver visual detection
MB5	Late pilot visual detection

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB9a	Take-off Hold Lights
PB11a	Airport Moving maps with traffic

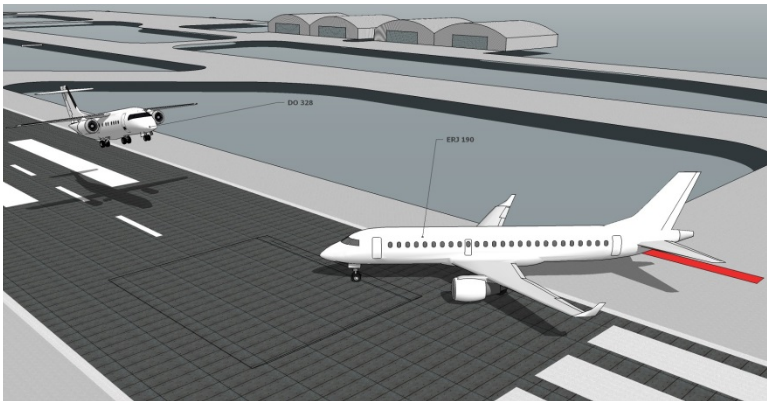
PB12	24H stop bars with procedures never to cross a lit bar
MB6	Sensor Controlled Incursion Projection System

8.18 Event 18: Taking-off with an aircraft entering the runway after mishearing its ATC clearance.

Generic Scenario

Taking-off on occupied runway	**C2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off as an aircraft/vehicle suddenly enters the runway contrary to its ATC clearance due to misinterpretation or mishearing the clearance**

Runway 15/33 was being used for both departure and arrivals. An ERJ-190 was taxiing for intersection departure for runway 33 and was instructed to "line up runway 33 after the departing Dornier 328", the crew read back "line up for take-off". The conditional clearance did not specify that the D328 was departing from the opposite direction.



The Dornier Do-328 was cleared to line up runway 15 and subsequently cleared for take-off from runway 15, as the Embraer went past the hold short line runway 33 and lined up runway 33. The Dornier rotated and climbed out over the Embraer.

The distance between the two runway entry points is 1350 meters.

Contributing factors:

Action – Incomplete Conditional Clearance
Perception (E190) – Pilot misheard clearance
Perception (ATC) – Misheard or did not hear incorrect readback
Perception (ATC)– Did not see E190 entering runway
Perception (E190) – Did not see D328 before entering runway

Actual Recovery Barrier:

MB5	Pilot visual detection

Barriers breached:

PB7	Pilot direct visual detection
MB1	ATC late visual detection
MB5	Late pilot visual detection (E190)
PBR	ATC RTF procedures

Remaining barriers available that could have reduced risk of collision:

X	Nil

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

PB12	24H use of illuminated stop bars and procedures never to cross a lit stop bar
MB6	Sensor Controller Incursion Projection System

8.19 Event 19: Incorrect take-off clearance given Taking-off with a vehicle inspecting the runway. ATC Hand over issues.

Generic Scenario

Taking-off on suddenly occupied runway	**A2b**	**Aircraft that is lined up is cleared for take-off or has commenced take-off. Aircraft/vehicle suddenly enters the runway due to it receiving an incorrect ATC clearance.**

The TWR positions were being combined into one for all active runways. The off-going controller gave a short handover on intercom. In relation to runway occupancy it was, "I've just given clearance for a runway inspection and you've got (call sign) CRJ9 taxiing for departure, any questions?" At the same moment, an aircraft transmitted on the frequency; however, the remaining controller did not question the handover.

The airport operations vehicle entered the runway 03/21 at the 03 threshold and proceeded northeast. The TWR controller initially instructed the CRJ9 to line up and wait on runway 21, but almost immediately cleared it for take-off. The visibility was good daylight and the presence of the vehicle was displayed on the flight data board and surface radar display.

At the time the CRJ9 began its take-off roll, the vehicle was heading towards it 1600m away. The RIM system alerted the controller as the aircraft and vehicle were 700m apart. The controller instructed the CRJ9 to abort take-off and then instructed the vehicle driver to vacate. By the time that the CRJ9 began to decelerate from 110kts, separation had decreased to 400m. The vehicle driver saw the CRJ9 approaching and steered towards the edge of the runway at 50Kts. The vehicle vacated the runway as the CRJ9 passed by, still doing 70kts. The lateral miss distance from wing tip to vehicle was 20m.

Contributing factors:

ATC Handover Issues
Perception – Did not handover information
Non-Conformance – Did not scan runway before giving take-off clearance
Perception – Did not see vehicle on runway
Perception – Did not see flight data runway block
Perception – Did not see conflict on SMR
Perception (pilot) – Did not see vehicle

Actual Recovery Barrier:

MB5	Driver visual detection

Barriers breached:

PB1	ATC memory aids
PB2	ATC direct visual detection

PB7	Pilot direct visual detection
MB1	ATC late visual detection
MB5	Late pilot visual detection (E190)
MB3	ATCO detection using Aerodrome Surface Movement System e.g. RIM

Barriers that, if deployed, could have prevented the runway incursion and/or reduced risk of collision:

MB7a	Take-off Hold Lights

Chapter 9
Summary of the Analysis of Actual Safety Events

This analysis aligns with the Safety Function Map (SAFMAP) methodology in considering the levels of barriers in any safety event chain in the following manner:

- What available barriers were breached in the event?
- What barrier stopped the event?
- What available barriers remained untested?
- What barriers may have reduced the risk of collision had they been deployed?
- What are the most common contributing factors?

9.1 What available barriers were breached in the event?

PB2	ATCO Direct Visual Detection	11
PB7	Pilot/Driver Visual Detection	10
PB1	ATC Memory Aids	8
PBR	ATC or Airport Operational Procedures	5
PBP	ATC RTF Procedures	4
MB1	Belated ATCO Direct Visual Detection	13
MB5	Belated Pilot/Driver Detection	6
MB3	ATCO Detection using Aerodrome Surface Movement System Inc. RIM	5

Table 11: The most common breached barriers

In more than half of the events, ATC did not visually detect the potential conflict prior to the runway incursion. ATC visual detection of the developing runway conflict was even worse. This suggests that serious runway safety events are not prevented because Aerodrome ATC has not adequately performed its primary function of visually monitoring the active runways.

Pilots or drivers did not visually detect the potential conflict on half of the events. Whilst the number is similar to ATC, it is less surprising. Pilots and drivers have a much smaller area of vision than ATC and are engaged in acts e.g. landing or taking-off, that require the bulk of their attention.
The non-use of ATC memory aids effectively featured in a significant number of events.

A quarter of the events would not have occurred had ATC used standard RTF phraseology correctly. Two of these events involved Conditional Clearances, whilst the other events involved phraseology that was open to (mis)interpretation.

A quarter of the events would not have occurred had ATC or Airport personnel complied with standard operational procedures.

ATC procedures that were breached included not checking a known cross-transmission and not positively confirming that an aircraft had vacated the runway.

Airport procedures breached included a driver using a private mobile phone whilst on runway duties and allowing an untrained airside person to communicate with ATC.

9.2 What barrier stopped the event?

MB5	Belated pilot/driver Visual Detection	16
MB1	Belated ATCO Visual Detection	1
MB3	ATCO Detection using Aerodrome Surface Movement system Inc. RIM	1
X	Providence	1

Table 12: The barrier that effectively stopped the event

This table shows that the large majority of collision risks were resolved by alert aircrew or drivers. On only one occasions did ATC visually detect the developing conflict before the pilot.

On only one occasion did a technical support system activate in time to mitigate the outcome. This suggests that there is currently a lack of effective system barriers. Once a Sudden High Energy Runway Conflict had been initiated, almost all of them have relied upon belated visual detection for collision avoidance.

9.3 What available barriers remained untested?

X	NIL	18
MB5	Belated pilot or driver detection (after other detection)	1

Table 13: The barriers that remained in place and untested when the event was stopped.

This table shows that if Pilot visual detection had not halted the event, there were no deployed barriers that would assist further.

9.4 What barriers may have reduced the risk of collision had they been deployed?

PB12	24H Stop bars and procedures never to cross a lit stop bar.	9
PB9	Runway Status Lights PB9b: Runway Entry Lights 5 PB9a: Take-Off Hold Lights 2	7
PB11	Airport Moving Maps PB11a: 2D with traffic on ND	3
PB8	Final Approach Runway Occupancy Signal (FAROS)	1
MB6 *	Sensor Controller Incursion Projection System	9*
MB7	Runway Status Lights MB7b: Runway Entry Lights 2 MB7a: Take-Off Hold Lights 2	4
	Nil	4

Table 14: The barriers that may have reduced the risk of collision if deployed.

Prevention:
The study of actual events suggests that the use of stop bars 24H together with procedures to never cross a lit stop bar or to give a clearance across a lit stop bar is the most effective preventative barrier available. It could have prevented around half of the actual serious runway incursions.

Runway Status Lights had the potential to prevent a minority but significant number of the real events.
Flight deck Airport Moving Maps can also add a layer of protection in a small number of scenarios.

Mitigation:
The study of actual events shows that almost all of SHERC events are mitigated and resolved by visual acquisition by a pilot or driver. The time available to ATC prevent a collision is likely to be less than the time needed to do so.

The Sensor Controlled Incursion Projection System (SCIPS) would be able to mitigate outcomes by alerting aircrew/drivers and ATC that an illuminated stop bar has been crossed. However, if the Prevention Barrier of 24H stop bars and strong procedures that they are never to be crossed was rigorously deployed, the SCIPS system would be of reduced value.

Runway Status Lights are potentially capable of assisting to mitigate some of the events.

9.5 Comparison of Actual Event Barriers with Generic Barrier analysis

The analysis of the barriers active in real events conforms strongly with the generic barrier exercise:

- The types of event whereby the use 24H Stop bars and associated procedures would be effective are more prevalent in the real world. The Generic study suggested that stop bars would only be effective in a quarter of SHERC scenarios; however, the prevalence of such incidents in reality increased the effectiveness of stop bars to almost half of actual events.
- Both Generic and Specific actual event studies show that visual detection by both ATC and Pilots/Drivers is a strong preventative barrier. However, once a SHERC event has been initiated only the late detection by pilot or a driver is effective.
- Both Runway Status Lights and Airport Moving Maps can be effective in some scenarios.

9.6 What are the most common contributing factors?

9.6.1 ATC

This study principally concerns ATC barriers. The first table shows the ATC contributing factors across the 19 events.

Perception	Not see one of the conflicting aircraft out of the window	12	24
	Not see conflict on strips	4	
	Not see visual info from RIM	3	
	Mishear RTF	3	
	Misperceive visual information	1	
	Not hear co-ordination	1	
Action	Convey incomplete information	5	14
	Convey no information to aircraft	3	
	Convey incorrect information	2	
	Convey unclear information	2	
	Convey no co-ordination	1	
	Mis selection of strip	1	
Memory	Forgot to scan	5	11
	Forgot previous action	4	
	No Recall from working memory	1	
	Recall from long-term memory	1	
Decision	Incorrect Plan	4	5
	Inadequate Plan	1	
Operational Environment	Distraction	2	5

	Visual Impairment from VCR 2 Noise in VCR 1	
Non-Conformance	Routine individual non-conformance 2 Isolated individual non-conformance 3	5
Training	Training - completeness Training - task familiarity	2
Team Factors	Splitting/Combining position issues	1
Personal Factors	Excessive Workload	1

Table 15: ATC contributing factors

This data is aligned with the barriers seen to be breached in the events. ATC contributing factors are primarily to do with Perception, followed by Actions and then Memory.

Far and away the most common contributing factor is a failure by ATC to see something and more than half of these factors involve not monitoring the external visual environment effectively.

The next most common area of concern is radio communication from ATC. These errors include incorrect information, insufficient information, ambiguous information and no information at all (where such was appropriate).

Of less prevalence were errors in planning. Largely, planning was correct, it was the failure to carry out the plan that was the principal error.

Whilst not shown above, it is of interest that 4 of the 12 ATC causal events was initiated immediately in response to other request or report. This is the same phenomenon described in an earlier EUROCONTROL NM Operational Safety Study called “Controller Blind Spot”.

It is also worthy of note that 2 of these serious events involved the use of Conditional line up clearances.

9.6.2 Pilot / Driver

Pilot/Driver contributing factors are principally those of Perception, followed by poor Communication techniques, as shown in the table below:

Perception	Not see conflicting aircraft 8 Mishear own clearance 5 Not see lighting/signage 3 Not hear clearance to other acft 3 Misinterpret lighting/signage 1	18

CRM Issues	Distraction due other duties 4 Not questioning clearance 2 Chain of command 1	6
Non Conformance	Deliberate departure from SOPs	5

Table 16: Pilot/Driver contributing factors

The information gleaned from this table conforms to all the previous insights. Situational Awareness is the key to pilot/driver performance.

9.6.3 Airport Procedures

The study of 19 events found examples of Airport procedures being contributing factors, these were:

- Use of Rapid Exit Taxiways (RET) for departures during mixed mode operations, thus reducing the opportunity for Situational Awareness for pilots at the holding point, especially at night.
- Permitting vehicles to cross illuminated stop bars or be inside stop bars from airside roads.
- Runway Ops vehicles not on same frequency as TWR controller.
- Runway Ops vehicles not under control of TWR controller.

Chapter 10
ATC Safety Nets

10.1 Methods to show an occupied runway

10.1.1 Runway occupied strip

This may be placed in a dedicated Strip holder of a different colour, usually red, to make it more noticeable.

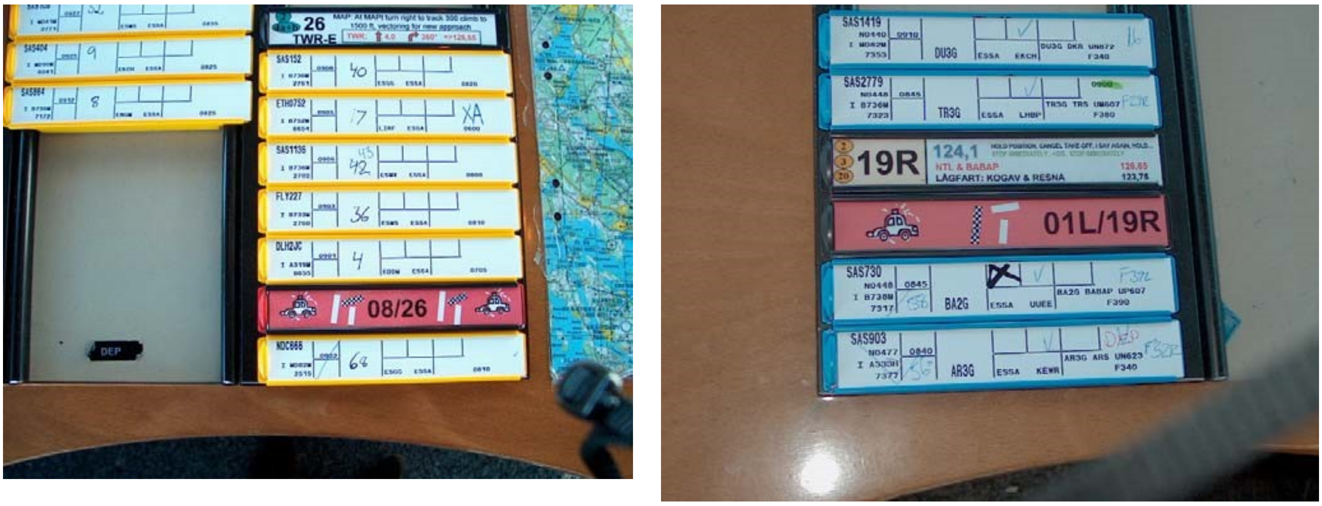


Fig 1 Dedicated flight strip for runway inspection (one per runway)

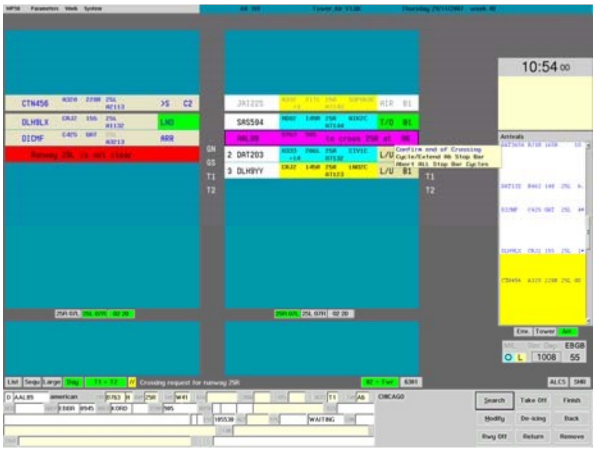


Fig 2 Electronic Flight Strip display with a clear indication in the left bay that a runway is occupied

10.1.2 Runway Occupied Boxes

Runway occupied boxes are a tool to remind a controller that the runway is occupied by a vehicle. It requires manual input by the controller. The controller places the box on the flight strip board during occasions when a vehicle is authorised to enter the runway. These types of devices normally have a flashing red light to remind the controller that the runway is occupied.

Flashing red light

Figure 3: "A runway occupied box" display panel

10.1.3 Runway Occupancy Plate

The Runway Occupancy Plate (ROP) is manually activated and de-activated by the controller and provides a reminder for the controller that a runway is obstructed or closed. The runway occupancy plate is built to physically represent the runway configuration. When the controller switches on the ROP, in addition to a flashing red light, which acts as a memory aid that the runway is obstructed, the wind information is suppressed from the meteorological displays.

It is a requirement when giving a take-off or landing clearance to transmit the actual surface wind. If the wind information is not available this will act as a further reminder that the runway is occupied. The wind information remains unavailable until the runway occupancy plate is switched off by the controller.

The occupied runway is indicated by a red light on the runway occupancy plate that blinks until a new input is made by the Air Traffic Controller after the driver reports "runway vacated". When a request is made for one hour or more, the status of the runway will be "CLOSED" and represented by a steady red light displayed on the runway occupancy plate.

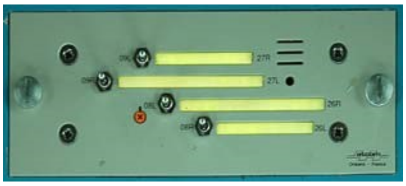


Figure 4. Runway open and free (all ROP lights are green)

Figure 5. Picture to the left (above) depicts the Runway closed and to the right the associated ATC MET Report Display is depicted with wind information suppressed. NOTE, when the runway is occupied the light is blinking red.

10.2 ATC Dedicated Tools

10.2.1 Advanced Surface Movement Guidance and Control Systems (A-SMGCS)

A-SMGCS covers applications and systems for the air traffic controller, vehicle drivers and the aircraft pilots. Operationally available systems offer:

- Controller surveillance display,
- Runway incursion alerts for the controller,
- Selective switching of taxiway lights, stop and hold bars
- Routing guidance functions and
- Runway protected areas penetration alerts and runway occupied alerts for the vehicle driver.

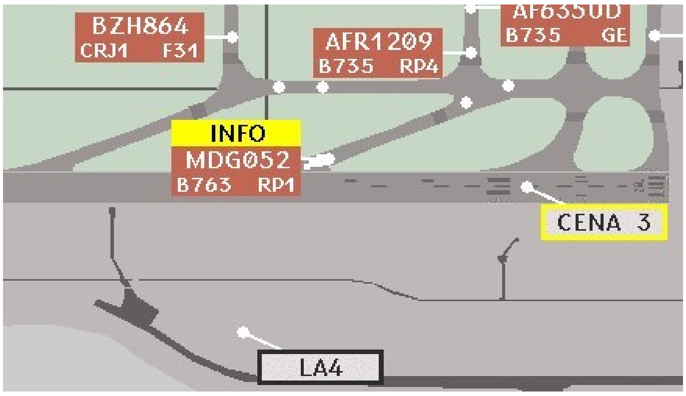


Figure 6. A-SMGCS display when an aircraft is in the runway strip and a car is on the runway.

The most common level of implementation of A-SMGCS across Europe is a Surface Movement Radar together with a Mode S multi-lateration system and a runway incursion alerting system in the air traffic control tower. A-SMGCS technologies can help to prevent runway incursions and conflicts between aircraft and vehicles on the manoeuvring area.

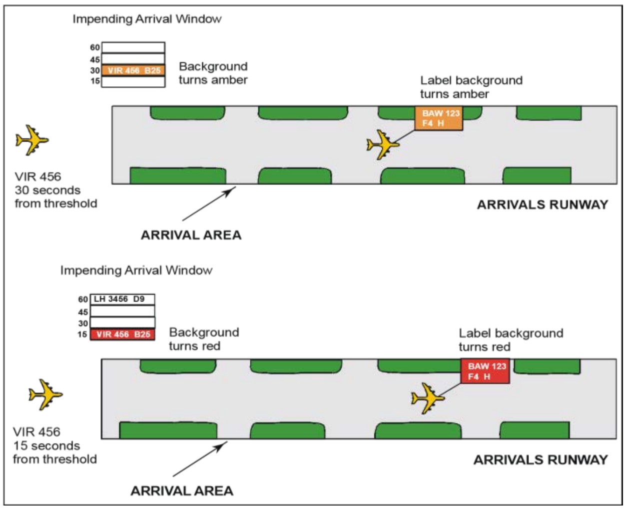


Figure 7: Example of A-SMGCS level II warning and alert in an approach scenario

The Predictive Runway Incursion Monitor (RIM) function generates two stage alerts at times determined by whether Low Visibility Procedures (LVPs) are in force. Typical values may be as follows.

RIM alert	Stage One Amber	Stage Two Red
Non-LVP	30 seconds	15 seconds
LVP	45 seconds	30 seconds

10.2.2 Conformance monitoring alerts and conflict detection

The introduction of electronic flight strips in many control towers means that instructions given by a controller are available electronically and can be integrated with other data such as flight plan, surveillance, routing and published rules and procedures. The integration of this data allows the system to monitor the information and alert the controller when inconsistencies are detected. This solution highlights potential conflicts much sooner than the current practise of relying on surveillance data to trigger an alarm. Taxi route deviations are among the most common alerts at large busy airports, but all alerts improve safety.

This solution is in the pipeline for delivery. Airport safety nets are due for synchronised deployment across Europe in accordance with the SESAR Pilot Common Projects.

This system, currently in development by SESAR detects when 2 clearances are considered as not safe or not allowed.

Any combination of:

- Landing clearance
- Take-Off clearance
- RWY Crossing clearance

- RWY Enter clearance
- Any combination considered as not safe or not allowed will trigger a Conflicting ATC Clearance alert
- There follows some examples of the information and alert messages generated in the so-called Integrated Tower working Position (ITWP) concept.
- The list is illustrative and not exhaustive.

10.2.2.1 Incorrect ATC Clearance

In this example the ATCO has input "cleared to land" on LGL8011 and a pop up window appears asking the ATCO if they really want to accept the condition

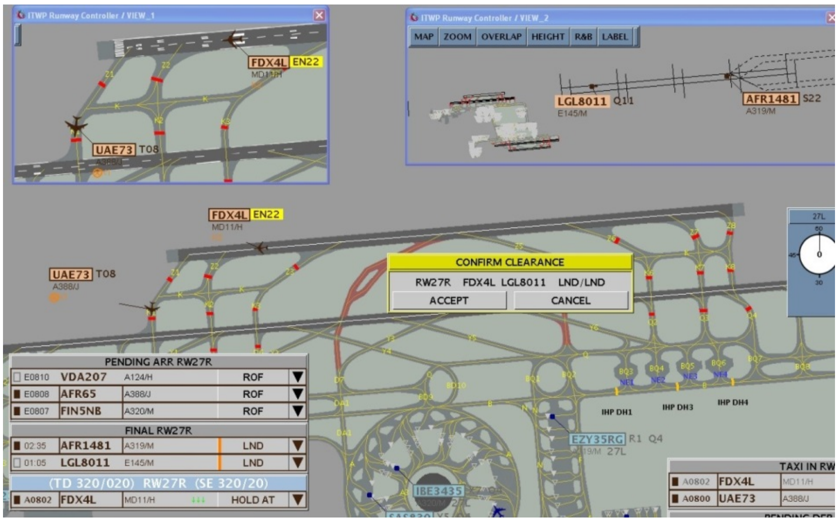


Fig 8. Pop up window in centre asks for confirmation of apparent conflicting clearances.

10.2.2.2 No Contact

This alert is generated for an aircraft on short final (less than 4NM) that is not on the RWY frequency.

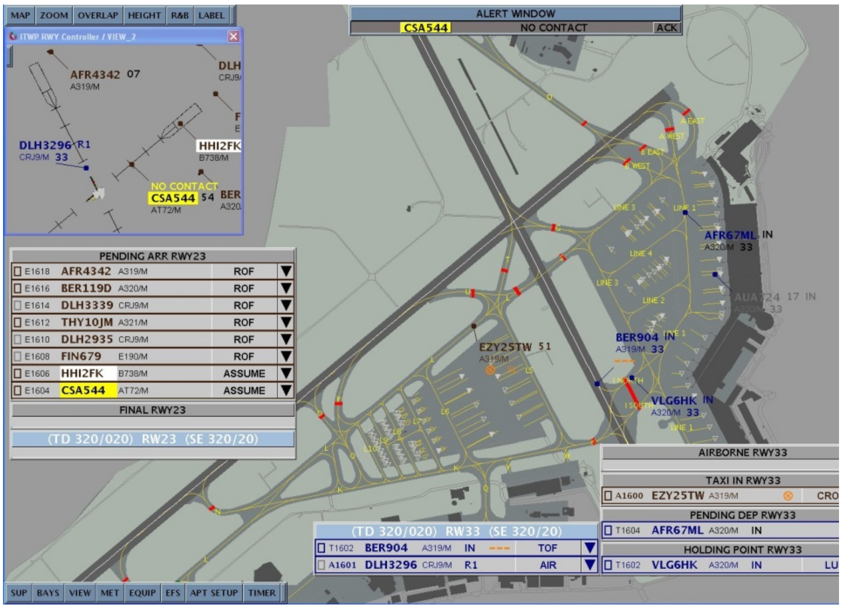


Fig 9. Yellow Highlight appears in Alert Window at top of display and yellow highlight on ATM element for no TWR frequency contact with an aircraft within 4 miles.

10.2.2.3 No Landing Clearance

This alert is generated when an aircraft is within 1nm of a runway threshold without a landing clearance

Fig 10. Red highlight appears in Alert Window at top of display and red highlight on ATM element and Arrivals elements for aircraft with no landing clearance within 1 mile.

10.2.2.4 No Line Up Clearance (NO LUP CLR)

This alert is generated when an aircraft is lining up the runway without a runway entry clearance.

Fig 11. Red Highlight appears in Alert window at top of display and red highlight in Holding point bay and runway entry point for an aircraft that is entering the runway without a clearance.

10.2.2.5 Deviation from cleared taxi route (ROUTE DEV)

Alerts are generated when an aircraft that is not taxiing in accordance with the clearance Cleared Trajectory is displayed once the deviation is detected.

Fig 12. Yellow Highlight appears in Alert Window at top of display and yellow highlight on aircraft symbol and in Taxi bay for an aircraft that has deviated from the cleared routing

Chapter 11
Airport Ground Safety Nets

11.1 Final Approach Runway Occupancy Signal (FAROS) and (eFAROS)

FAROS is an FAA-sponsored concept, which is being deployed for operational evaluation in the USA, along with other elements of the system of Runway Status Lights.

It works by providing a visual signal to aircraft on final approach to land that the runway ahead is occupied by another aircraft or a vehicle. This is done by adapting the PAPI or VASI system to alter from steady lights to flashing mode whilst the identified hazard remains. Externally, the PAPI or VASI system is unaltered and continues to function normally in its primary role as an angle of approach awareness indicator whether or not a FAROS input has temporarily caused the flashing mode to activate.

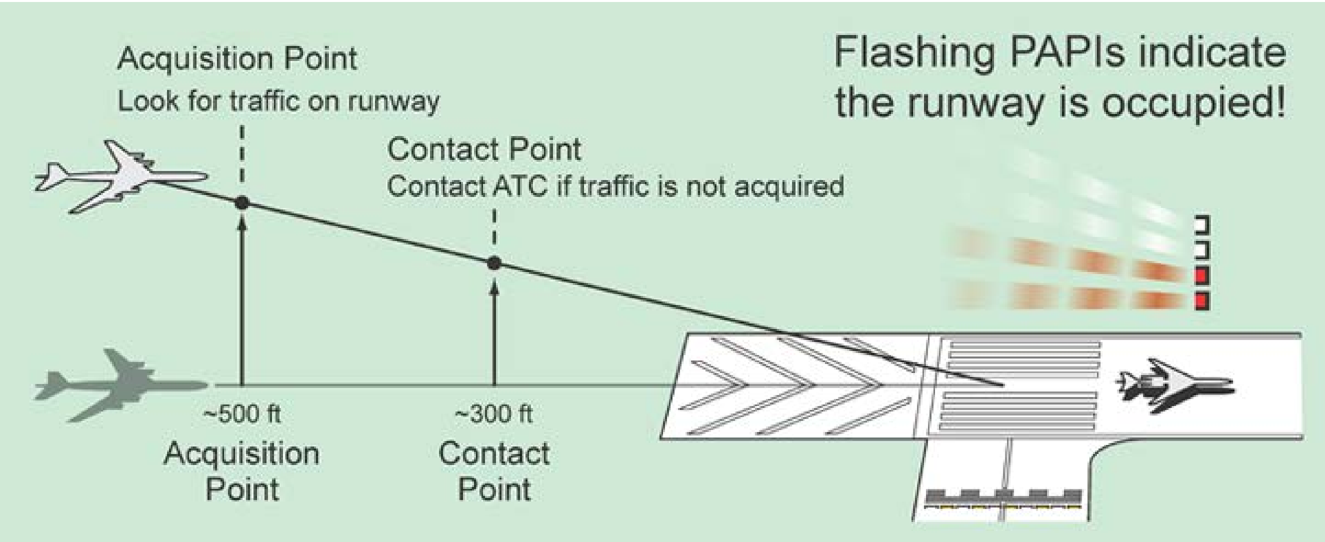


Fig. 13 Pilot Protocol for FAROS

The input signal to the FAROS visual signal is provided automatically by the embedded inductive loops which are installed at all runway entry and exit points and which are able to detect transiting traffic by the disturbance of the loop magnetic field which it causes.

eFAROS is an experimental system autonomously driven by safety logic based on aircraft location from airport surveillance radars (ASRs), surface detection radars (ASDE-3 or ASDE-X), and multilateration information from the ASDE-X surveillance system. The FAA expects eFAROS to prevent the occurrence of both runway land-over incidents and occupied runway accidents. eFAROS provides a signal of runway occupancy directly to pilots.

11.2 Autonomous Runway Incursion Warning System (ARIWS)

The operation of an ARIWS is based upon a surveillance system which monitors the actual situation on a runway and automatically returns this information to warning lights at the runway (take-off) thresholds and entrances. When an aircraft is departing from a runway (rolling) or arriving at a runway (short final), red warning lights at the entrances will illuminate, indicating that it is unsafe to enter or cross the runway. When an aircraft is aligned on the runway for take-off and another aircraft or vehicle enters or crosses the runway, red warning lights will illuminate at the threshold area, indicating that it is unsafe to start the take-off roll.

In general, an ARIWS consists of an independent surveillance system (primary radar, multilateration, specialized cameras, dedicated radar, etc.) and a warning system in the form of extra airfield lighting systems connected through a processor which generates alerts independent from ATC directly to the flight crews and vehicle operators. An ARIWS does not require circuit interleaving, secondary power supply or operational connection to other visual aid systems.

In practice, not every entrance or threshold needs to be equipped with warning lights. Each aerodrome will assess its needs individually depending on the characteristics of the aerodrome. There are several systems developed offering the same or similar functionality.

Pilots are presented with a globally consistent signal which means “STOP IMMEDIATELY” and must be taught to react accordingly. Likewise, pilots receiving an ATS clearance to take-off or cross a runway, and seeing the red light array, must STOP and advise ATS that they aborted/stopped because of the red lights. Again, the criticality of the timeline involved is so tight that there is no room for misinterpretation of the signal. It is of utmost importance that the visual signal be consistent around the world.

11.2.1 Runway Status Lights (RWSL)

Runway Status Lights (RWSL) is a type of autonomous runway incursion warning system (ARIWS).

The two basic visual components of RWSL are runway entrance lights (RELs) and take-off hold lights (THLs). Either may be installed by itself, but the two components are designed to be complementary to each other.

It is possible that the two RWSL elements and the Final Approach Runway Occupancy Signal (FAROS) system may be integrated in the future.

11.2.1.1 Runway Entrance Lights (RELs)

RELs are installed at taxiway/runway intersections to provide an indication when it is unsafe to enter the runway. The first light in the pattern is installed 2 feet prior to the runway holding point marking. They continue to a penultimate light pair at 2 feet before the runway edge marking with the last light then sited 2 feet before the runway centreline lights.

RWSL safety logic process accepts fused surveillance from three sources: 1) Primary radar returns from the Airport Surface Detection Equipment; 2) Time difference of arrival multilateration utilizing interrogation and replies from transponder-equipped aircraft and vehicles, and 3) the terminal radars used for air traffic control. The fused logic determines the operational state of the track (e.g., stopped, taxiing, landing, or departing), predicts likely future behaviour based on the current state, and determines when and which lights should be illuminated. Location of traffic and their dynamics states drive the decision-making process for light illuminations. A simplified example of how RWSL safety logic determines when RELs should turn on and off along a runway during a departure operation is provided in the table below:

Aircraft Behaviour	Stopped on the runway awaiting take-off clearance	Begins departure roll	Becomes a high-speed operation (> 25 kts)	Passes taxiway intersections	Rotates and begins climbing
RWSL State	STP (stopped)	TAX (taxi)	DEP (departure)	DEP (departure)	AIR (airborne)
RELs	OFF	OFF	ON	OFF at no threat locations, ON downfield	All locations OFF

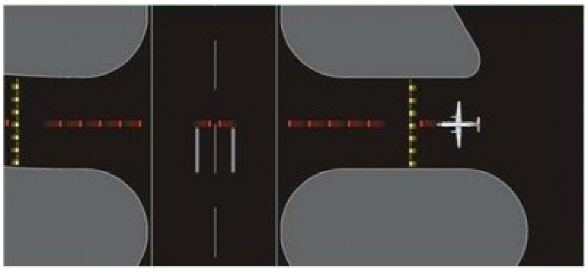


Fig 14. Illuminated RELs as seen from above

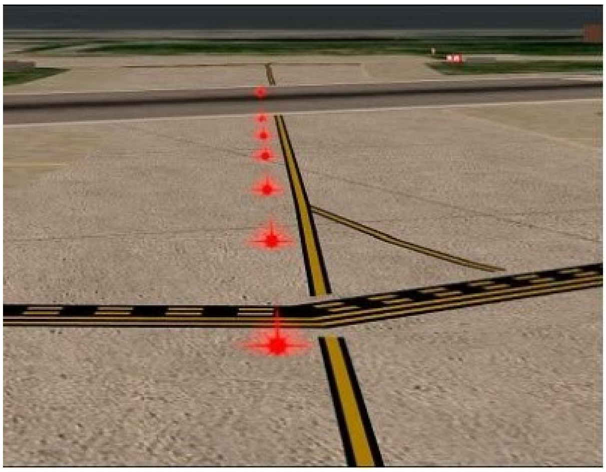


Fig 15. Pilot view of illuminated RELs

11.2.1.2 Take Off Hold Lights (THLs)

THLs are used at the runway departure area and provide an indication to pilots that the runway is unsafe for take-off. They consist of red unidirectional lights installed in two longitudinal rows of 16 lights each aligned with and offset either side of the runway centreline lighting.

The rows of warning red lights are positioned either side of the runway centreline commencing 115m from the threshold to 540m from the threshold.

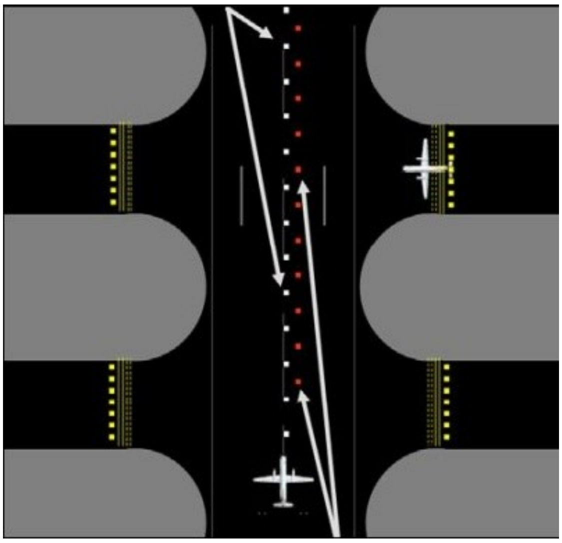


Fig 16. Take off Hold Lights from above

Fig.17 Pilot view of Take-off Hold Lights

11.3 Sensor Controlled Incursion Protection System (SCIPS)

This system is a combination of an ATC safety alert and also a visual incursion alert to the pilot.
It requires that a stop-bar is illuminated and crossed. From a pilot perspective, when an illuminated stop bar is crossed, the aircraft breaks a beam at Sensor A in the Figure 18 below. This in turn triggers an array of lights, in the shape of a Red T, to be lit ahead of the aircraft. (See Fig 19 below). At the same time, ATC receive an audio alert that a stop bar has been crossed. The system also captures events where an aircraft vacating the runway does not clear the Protected Area within a defined time. The system is primed as the aircraft breaks the beam at Sensor B (see Fig. 18) and triggers an alert if the aircraft does not cross the beam at Sensor A within the set time.

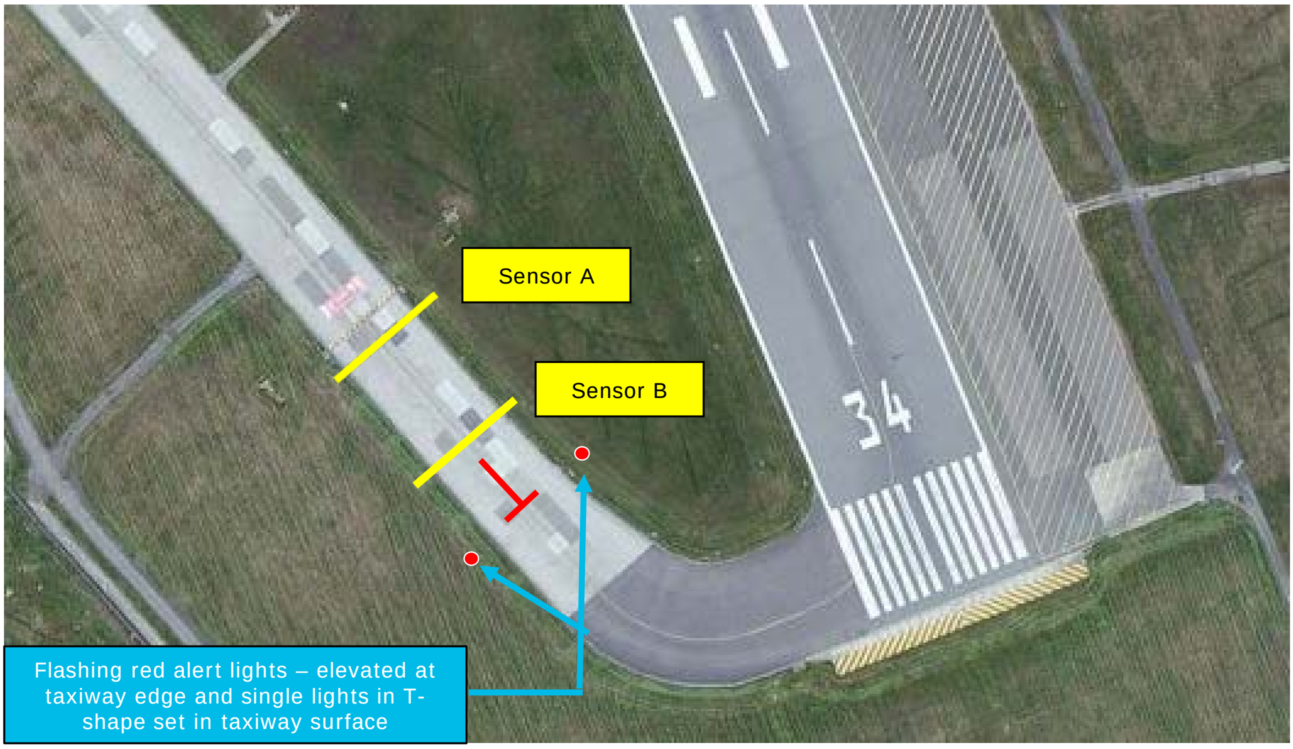


Fig 18. SCIPS system[4]

Fig. 19 Pilot view of SCIPS alert. Crossing an illuminated stop-bar results in array of Red Lights.[5]

[4] Used with permission from ADB Airfield Solutions and AGS Airports
[5] Used with permission from ADB Airfield Solutions and AGS Airports

11.4 Ground-based augmentation of satellite navigation systems (GBAS)

GBAS uses four global navigation satellite system (GNSS) reference receivers and a VHF broadcast transmitter system. Its ground system measures distances to GNSS satellites (e.g. Galileo), and computes error corrections and integrity data based on-signal quality and known fixed positions of the GNSS reference receivers. Together with the approach path and quality information the corrections are broadcast as digital-coded data to all GNSS landing system (GLS)-equipped aircraft within range. The aircraft receives this information, calculates the (differentially) corrected position and deviations from the selected approach path, allowing it to land automatically in low-visibility conditions.

In terms of this study, the introduction of GBAS would reduce the likelihood of events involving errors of positioning and situational awareness.

Chapter 12
Pilot Safety Nets

12.1 SmartRunway & SmartLanding

SmartRunway & SmartLanding is a development of the Runway Awareness and Advisory System (RAAS) and is available on later-model Enhanced Ground Proximity Warning Systems. It provides information to pilots on (which) runway is ahead both airborne and on the ground.

Runway Awareness and Advisory Systems use airport data stored in the EGPWS database, coupled with GPS and other on-board sensors, to monitor the movement of an aircraft around the airport. It provides visual/aural annunciations at critical points, such as "Approaching Runway 09 Left and confirmation when an aircraft is lined up on the runway prior to take-off: for example, "On Runway 09 Right, 2,450 metres remaining." In a scenario where a crew inadvertently lines up on a parallel taxiway and commences a take-off, an aural alert “On Taxiway, On Taxiway” is provided if the aircraft speed exceeds 40 kts, 74.08 km/h or 20.56 m/s.

Advisories/cautions are generated based upon the current aircraft position when compared to the location of the airport runways, which are stored within the EGPWS Runway Database. These advisories include:

- **Approaching Runway** – An ‘In Air’ advisory provides the crew with awareness of which runway the aircraft is lined up with on approach.
- **Approaching Runway** – An ‘On-Ground’ advisory provides the flight crew with awareness of approximate runway edge being approached by the aircraft during taxi operations
- **On Runway** advisory provides the crew with awareness on which runway the aircraft is lined-up.

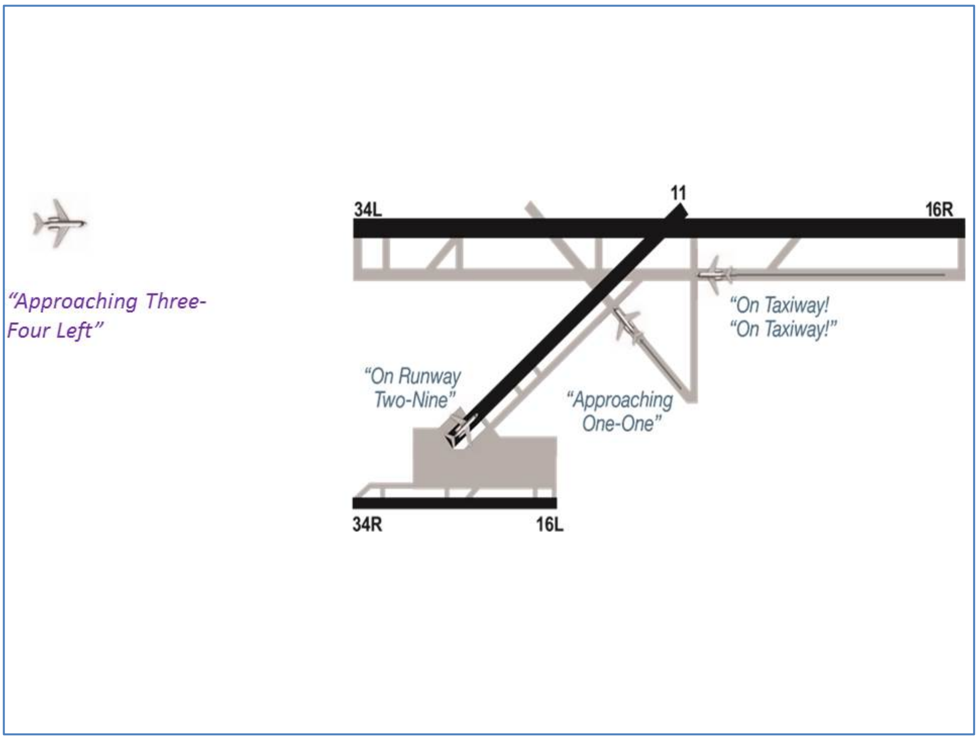


Fig. 20 SmartRunway and SmartLanding[6]

12.2 2D Airport Moving Map with Traffic

This is situated on the Navigation Display on the Flight Deck. It shows the aircraft situation in relation to the “bigger picture”. It includes runway hot spots and moving aircraft symbols. It will also include airport vehicles that are fitted with ADS-B out capability.

Fig 21 2D Airport Moving Map on Flight Deck Navigation Display[7]

[6] Used with permission from Honeywell International Inc. Copyright Honeywell international Inc.
[7] Used with permission from Honeywell International Inc. Copyright Honeywell international Inc.

12.3 3D Airport Moving Map

This system is placed onto the Primary Flight Display. It presents similar to an automobile GPS. It utilises the perspective of a position above and behind the subject aircraft. On turning onto a runway however, the display changes to a conventional looking ahead from the Flight Deck view. At present, the 3D version does not show traffic. This is a growth item for the future.

Fig 22. 3D Airport Moving Map on Flight Deck Primary Flight Display[8]

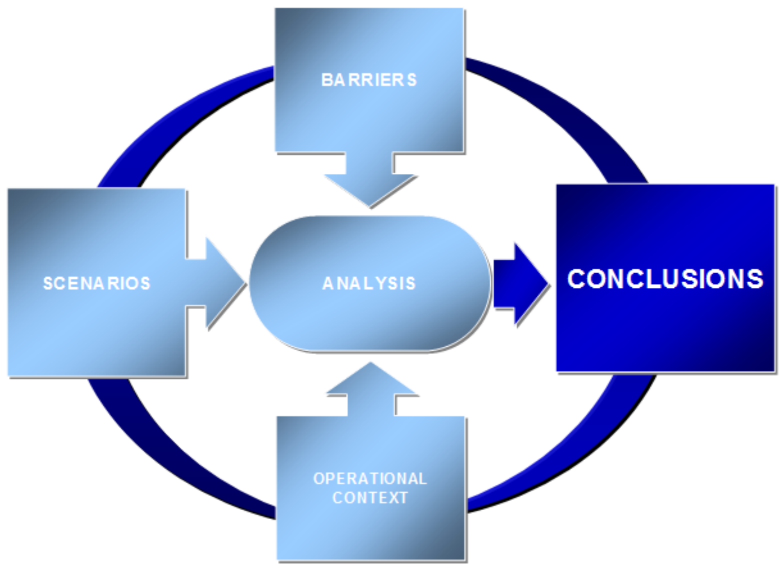
12.4 Flight Deck Taxi Wizard

This display shows the pilot the standard taxi routing from parking stand to runway holding point. It can be adjusted by ATC clearance. It can be entered either by downlink, such as D-TAXI, or by manual input.

Fig 23 Flight Deck Taxi Wizard[9]

[8] Used with permission from Honeywell International Inc. Copyright Honeywell international Inc.

Chapter 13 Conclusions and Recommendations



[9] Used with permission from Honeywell International Inc. Copyright Honeywell international Inc.

Conclusion 1	This study concurs with and supports the FAA National Runway Safety Plan conclusion that an incorporation of multiple layers of technology is currently the most effective response to Sudden High Energy Runway Conflicts.
Conclusion 2	This study identified twelve barriers available that could potentially prevent runway incursions that, if not halted, could escalate into Sudden High Energy Runway Conflict events. It was established that no barrier by itself has the potential to prevent more than 35% of identified potential scenarios. It is concluded that a combination/s of the following barriers have the highest potential to prevent Sudden High Energy Runway Conflicts: ❑ ATC Conformance Monitoring and Conflicting Clearances Alerts. ❑ The correct use of ATC memory aids. ❑ The use of stop bars 24H together with procedures never to cross an illuminated bar. ❑ Autonomous Runway Incursion Warning Systems (such as Runway Status Lights). ❑ Flight deck Airport Moving Maps.
Conclusion 3	The study identified seven barriers that might mitigate the collision risk. Once a Sudden High Energy Runway Conflict event had been initiated, almost all of them relied upon belated visual detection from aircrew/drivers for collision avoidance. There is currently no functionality available that will provide timely alerts involving movement on two intersecting runways. It is concluded therefore that there is currently a lack of an effective system barrier that can make a significant impact in reducing the risk of collision.
Conclusion 4	Visual detection by ATC of SHERC events is limited by meteorological conditions and is unlikely to be effective once the event has been initiated. It is concluded therefore that ATC training should emphasise the importance of Prevention of SHERC events, focussing on the correct use of memory aids, visual vigilance and precise ATC clearances.
Conclusion 5	The use of stop bars 24H together with procedures to never cross a lit stop bar or to give a clearance across a lit stop bar could have prevented almost half of the actual serious runway incursions studied. It is concluded therefore that there are significant safety gains available from this established safety barrier with appropriate procedures.

Recommendation 1	**European ANSPs and Airport Authorities review the identified potential barriers and the conclusions in case they undertake operational safety analysis and improvement activities for Sudden High Energy Runway Conflict events.**
Recommendation 2	**European ANSPs and the EUROCONTROL Safety Improvement Sub-Group (SISG) monitor occurrences involving Sudden High Energy Runway Conflict to determine changes in frequency and severity.**
Recommendation 3	**All European industry stakeholders support the development of procedures, tools and functionality that have the potential to prevent or mitigate the high collision risk that is present in Sudden High Energy Runway Conflicts.**
Recommendation 4	**All European industry stakeholders promote and support the deployment and use of H24runway stop bars with procedures to never cross an illuminated stop bar or to give a clearance across an illuminated stop bar, subject to contingency procedures.**
Recommendation 5	**All European industry stakeholders to note that the consistent use of memory aids, correct and precise phraseology and visual vigilance by both ATC and Pilots/Drivers can combine to create a strong preventative barrier. Training and competence programmes should reinforce these essential activities.**

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