Network Manager
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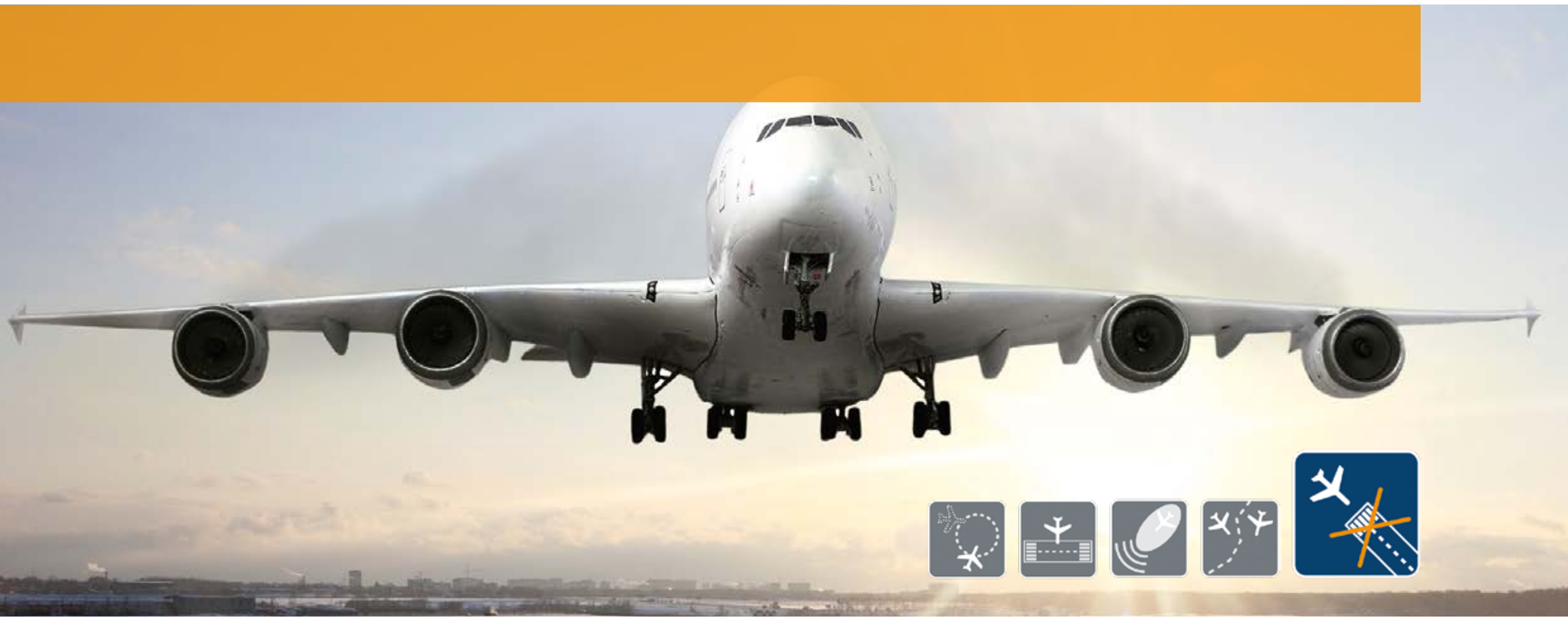
EUROCONTROL

Operational Safety Study: Landing without ATC clearance



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

Authority	Name and signature	Date
Operational Safety Coordinator, DNM/NOM/SAF	Mr. Tzetomir Blajev	19/05/2014
Head of Safety Unit, DNM, NOM	Mr. Antonio Licu	19/05/2014
Head of Network Operations Management Division	Mrs. Nicola Cooper	20/05/2014
Director NM	Mr. Joe Sultana	20/05/2014

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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 review during summer 2012 and involved a series of dedicated workshops with 6 ANSPs, representing a large part of European air traffic.

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
- Landing without ATC clearance
- Detection of occupied runway
- "Blind spot" – inefficient conflict detection with the closest aircraft
- Conflict detection with adjacent sectors

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 2013 - "Landing without ATC clearance".
- To serve as a reference for the Network actors in case they undertake operational safety analysis and improvement activities for landing without clearance.

The priorities were reviewed by SISG with SAFMAP analysis of the data for year 2013 and re-confirmed as Top 5 priorities for 2014.

The methodology employed was as follows:

- Generate a set of generic scenarios that could result in a Landing without Clearance.
- Consider what barriers exist that if implemented and deployed could prevent a Landing without Clearance.
- Consider what barriers exist that if implemented and deployed could mitigate the result of a Landing without Clearance.
- Analysis each generic scenario against the potential barriers to establish which of these barriers could be effective over the whole range of scenarios.
- Review a set of actual events to confirm that the barriers suggested by the generic analysis to validate that the same barriers should be the most effective in the live environment.
- Review other published study data and conclusions to check upon convergence and source new information and ideas.

This report has found a very high correlation between the generic analysis and the review of real events. Other studies have provided valuable confirmatory evidence.

The Conclusions detail the Top 4 potential prevention barriers and the Top 4 mitigation barriers. Combinations of these barriers will provide even greater safety gain.

There is also evidence that a combination of prevention barriers could be developed as set together. This may include low cost technical developments.

Recommendations are made to Stakeholders, including Airport Authorities, Air NavigationService Providers, Aircraft Operators, Aircraft Manufacturers, Ground Service Operators, Pilots, ATCOs and vehicle drivers. Most of the recommendations require representatives of all parties to work together to obtain the safety benefits that are available.

CHAPTER 1 - INTRODUCTION

1.1 What is the purpose of this document?

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 2013 and 2014 - "Landing without ATC clearance". ■ To serve as a reference for the Network actors in case they undertake operational safety analysis and improvement activities for landing without clearance.

1.2 What are the Network Manager Top 5 ATM Operational Safety Priorities for 2013 and 2014?

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".
Landing without ATC clearance	For various reasons, aircraft sometimes land without ATC clearance resulting in Runway Incursions that are often only resolved by 'providence'.
Detection of occupied runway	Some Runway Incursion incidents could have been prevented if controllers had had better means to detect that the runway was occupied at the time of issuing clearance to the next aircraft to use the runway.
"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 after a descent clearance and in the context of a rapidly developing situation - often when the conflicting aircraft are 1000ft and 15 nm apart.
Conflict detection with adjacent sectors	Losses of Separation in the En-Route environment sometimes involve "inadequate coordination" of clearance with an adjacent sector. These typically involve either an early (premature) transfer of control to or from the neighbouring sector.

1.3 How did we identify the 'Top 5'?

The Network Manager identifies Network safety issues to enable aviation stakeholders to mitigate 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, was tasked to identify the Top 5 ATM Operational Safety Priorities. In 2012, 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 list of agreed priority areas contains 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".

The review was performed during summer 2012 and involved a series of dedicated workshops with 6 ANSPs, representing a large part of European air traffic.

The second step was a detailed review with SAFMAPS.

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:

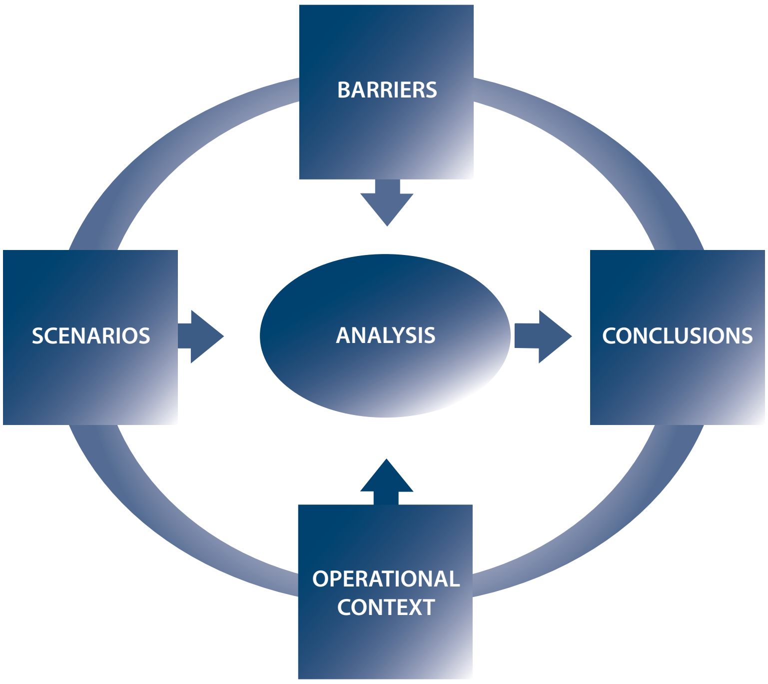
- Risk of operation without transponder or with a dysfunctional one
- Landing without ATC clearance
- Detection of occupied runway
- "Blind spot" – inefficient conflict detection with the closest aircraft
- Conflict detection with adjacent sectors

The priorities were re-confirmed for 2014

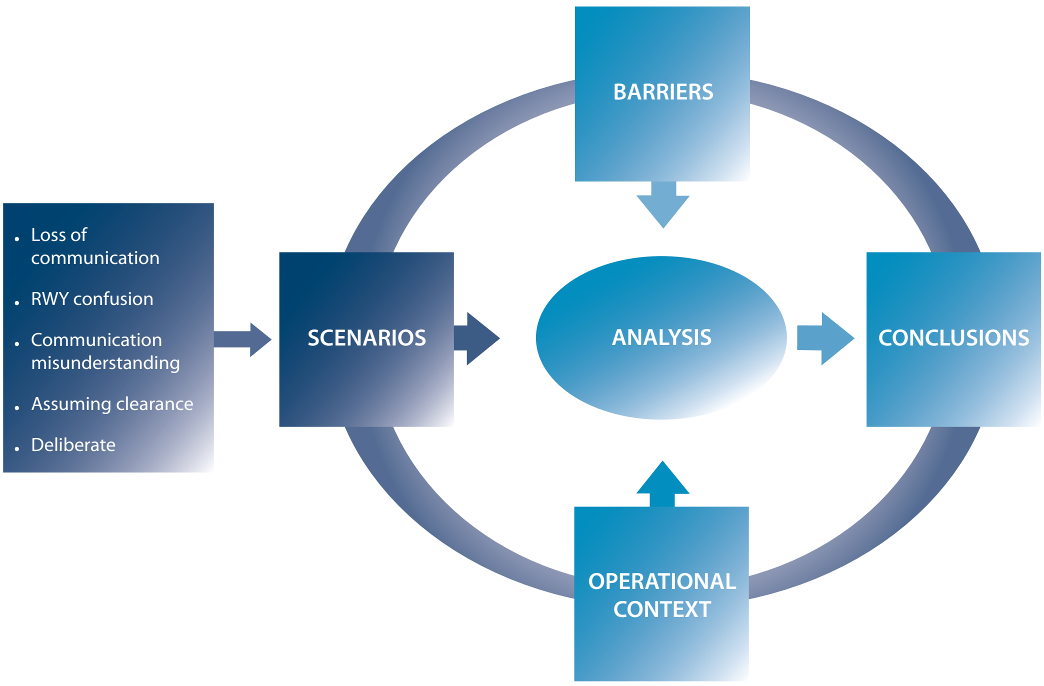
The priorities were reviewed by SISG using the same approach of analysing the high severity incident with SAFMAPs. As a result SISG re-confirmed the Top 5 priorities for 2014.

CHAPTER 2 - THE GENERIC PROCESS: OVERVIEW

The figure below provides an overview of the generic steps in the Operational Safety Study



CHAPTER 3 - GENERIC SCENARIOS



3.1 How should generic operational scenarios be defined?

Generic operational scenarios are used to help reduce the complexity of the subsequent analysis. Scenario definition is by "story telling", specific to help assess the effectiveness of the proposed safety barriers and generic enough to keep their number relatively small. The scenarios draw upon two sources of information:

Combination of top-down and bottom-up approaches

- A systematic analytical de-construction of each operational scenario into sub-scenarios. This is based on all theoretically possible combinations of 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.

3.2 Analytical deconstruction of operational scenarios

The following reasons for landing without clearance were identified:

Scenario Sources

A. Loss of communication
B. Runway confusion
C. Communications misunderstanding
D. Absence of clearance overlooked by the pilot(s)
E. Deliberate

The mechanisms as a scenario element describe the flight after the scenario sources occurred. In the case of Landing without clearance it can happen during the final phases of the flight:

Scenario Sources

- During Final approach
- During Landing
- During go-around

The review of the scenario mechanisms revealed that they are not providing any important differentiation of the scenarios in terms of risk and are therefore irrelevant for this operational study. The scenario mechanisms were not retained further.

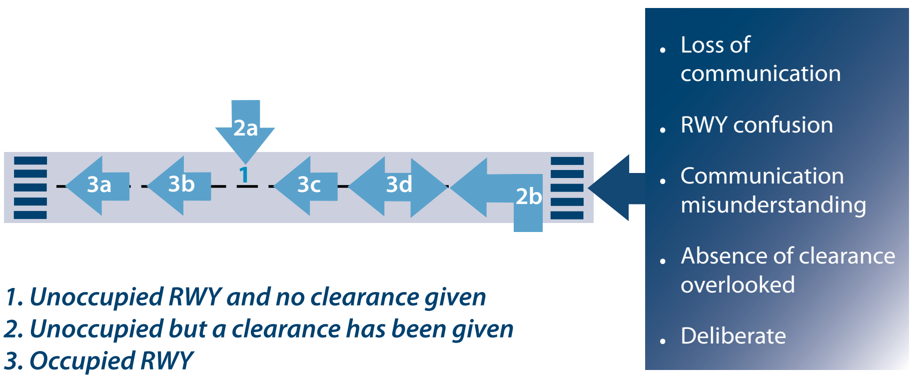


Figure 1: Landing without clearance scenarios

Scenario Outcome

The traffic situation related to the runway at which a landing without clearance potentially occurs is illustrated on the figure above and can be described by one of the options:

1. **Runway unoccupied and no other clearance for its use has been given**
2. **Runway unoccupied and another clearance for its use has been given:**
   a. To cross (aeroplane or vehicle)
   b. To enter (Aeroplane line-up or vehicle)
3. **Runway occupied by:**
   a. A previously landed aeroplane
   b. An aeroplane on take-off roll
   c. An aeroplane which has rejected its take-off or is doing so
   d. A vehicle
   e. An aeroplane lined up for departure

The resulting list of generic operational scenarios for analysis

A1 Landing without clearance after loss of communication on an unoccupied runway when no other clearance for the runway has been given.

A2 Landing without clearance after loss of communication on an unoccupied runway when another clearance for the runway has been given.

A3 Landing without clearance after loss of communication on an occupied runway.

B1 Landing without clearance after runway confusion on an unoccupied runway when no other clearance for the runway has been given.

B2 Landing without clearance after runway confusion on an unoccupied runway when another clearance for the runway has been given.

B3 Landing without clearance after runway confusion on an occupied runway.

C1 Landing without clearance after communication misunderstanding on an unoccupied runway when no other clearance for the runway has been given.

C2 Landing without clearance after communication misunderstanding on an unoccupied runway when another clearance for the runway has been given.

C3 Landing without clearance after communication misunderstanding on an occupied runway.

D1 Landing without clearance after the absence of clearance was overlooked on an unoccupied runway when no other clearance for the runway has been given.

D2 Landing without clearance the absence of clearance was overlooked on an unoccupied runway when another clearance for the runway has been given.

D3 Landing without clearance the absence of clearance was overlooked on an occupied runway.

E1 Deliberate landing without clearance on an unoccupied runway when no other clearance for the runway has been given.

E2 Deliberate landing without clearance on an unoccupied runway when another clearance for the runway has been given.

E3 Deliberate landing without clearance on an occupied runway.

3.3 Examples of actual landing without clearance events

Landing without clearance after loss of communication

- The Private Pilot flying a single engine light aircraft mistuned the TWR frequency whilst struggling to fly a non-precision approach in IMC and assumed that the subsequent lack of contact was the result of radio failure. The approach was continued until the runway was acquired visually and a landing over the top of an apparently unseen twin turbo-prop lined up for departure occurred.
- A VFR light aircraft on a local flight returned to the airfield having lost communication. ATC was unaware until the aircraft overflew the runway waggling its wings after which it completed a circuit and landed.

Landing without clearance after runway confusion

- At an airport with two parallel runways, the one usually used for landing having been closed for the previous three months for major maintenance with NOTAM action in place, an arriving regional jet crew making a visual approach in excellent visibility and light surface winds asked to use 01R rather than in the reciprocal 'in-use' direction 19L and was cleared to land accordingly with a correct readback. Neither the pilots nor the controller realised that the aeroplane subsequently landed on the closed 01L until it had done so. There were no fixed obstacles on the runway but the required closed runway markings were present. The crew stated that they had not noticed these and attributed their error to entering the wrong runway in their FMS.
- With two aerodromes 3 miles apart, fast jet VFR traffic with a landing clearance at one, a military base, unexpectedly turned finals and landed at the other, a large commercial airport. ATC at the commercial airport observed the error when the aircraft appeared on final approach and ensured that the runway was clear for the potential landing.

Landing after communication misunderstanding

- ATC advised the pilot of an xxxx to "expect late landing clearance" and received the read back "landing clearance" with the abbreviation going unchallenged. The pilot believed that he was cleared to land and did so.
- ATC instructed a pilot of an xxxx to continue the approach when at a range from touchdown of xxxx. There was no further communication and the pilot, believing that he must have received a landing clearance, continued to a landing. ATC were distracted by an operational phone call.

- The pilot of an xxxx was asked when the aeroplane was at 10 nm final to continue the approach and call back at 4nm final for landing clearance. The aeroplane continued and landed without clearance just after an inspection vehicle had cleared the runway.
- The pilot of an xxxx asked when the aeroplane was on final approach to reduce speed and change to the frequency of TWR. There was no read back of the frequency and at 1 nm the pilot asked APP if there was a clearance to land.
- The pilot of an xxxx did not change the frequency to TWR after reading back the instruction to do so. The TWR controller did not try to call the aircraft until after it had landed and observed that he hadn't been aware of the aircraft involved because of a busy situation with other traffic.

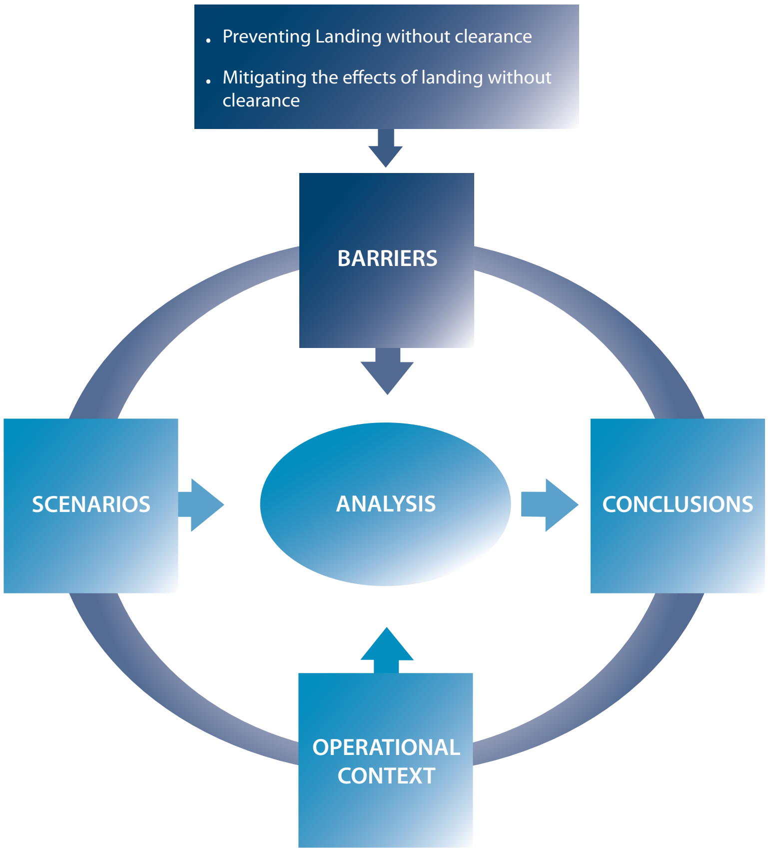
Landing without clearance after the absence of clearance was overlooked

- After the first contact with the TWR the crew of an xxxxx was instructed to continue approach and to expect to be called back. After landing without clearance, the crew commented that landing clearances at this airport are a problem because they are often given a long way out when there are 2/3 preceding aeroplanes so that the absence of the promised call back with clearance was easily missed when it is rare to issue landing clearances on short final.
- The pilot of an xxxx was changed frequency to TWR but remained on the APP frequency landed and asked for a taxi route. TWR didn't notice that it wasn't on frequency and observed that APP is permitted to keep aeroplanes on its frequency and issue a landing clearance.
- An xxxxx contacted TWR while it was No 2 in the approach sequence and was instructed to reduce to minimum approach speed and continue. The TWR controller then forgot about the aeroplane. It was noted that the controller had marked the corresponding strip at the time of the first contact with the aeroplane as if it had already been cleared to land.
- An xxxx was given a speed reduction, wind information and an instruction to continue the approach. The controller then forgot the lack of clearance and the frequency was so busy that the crew was unable to transmit. They continued the approach and landed without clearance.

Deliberate landing without clearance

- A light aeroplane lost positional awareness, saw what was considered to be a convenient airport and proceeded to join the circuit and complete an approach and landing without radio contact. The TWR controller saw the aeroplane when it was downwind and instructed another aeroplane making an approach in the opposite

CHAPTER 4 - BARRIERS



4.1 Barriers as opportunities in some situations

Opportunity versus responsibility

The Barriers included in this risk analysis have been identified as possible ways that Landing without Clearance could be prevented or the consequences mitigated. Their inclusion does not imply that they relevant to all situations and neither does it imply that their adoption by aircraft operators or ANSPs as a group would necessarily be appropriate. It may be possible to identify more potentially useful barriers than are included here.

4.2 Two types of barriers

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 landing without clearance events. The figure below represents a generalised SAFMAP for Landing without clearance.

This generalised SAFMAP is derived from the Level 0 Runway Collision SAFMAP and is the most generic barrier model for preventing runway collision because of situations of landing without clearance.

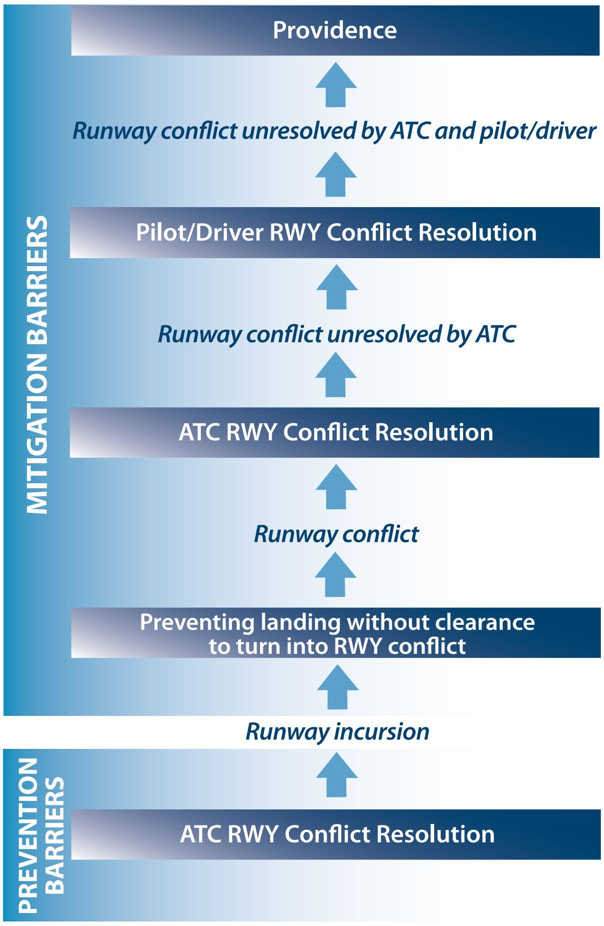


Figure 2: Generalised SAFMAP for Landing without clearance

There are two sets of barriers which can reduce the risk associated with landing without clearance. These barriers are found in both aircraft operation and air traffic control and have been identified from both a wide literature search and from consultation. These are:

Balancing preventing and mitigating the risk associated with landing without clearance

- **Barriers to prevent the occurrence of landing without clearance.** These barriers are specific for the landing without clearance type of runway incursion.
- **Barriers to mitigate the consequences of landing without clearance.** These barriers are general to runway collision avoidance, but their effectiveness for landing without clearance scenarios is explicitly reviewed in Chapter 6 of this report.

4.3 Barriers which may prevent landing without clearance

Barriers preventing landing without clearance

PB1 Trigger for pilots to check landing clearance - SOP to select the landing/taxi lights on only when clearance to land is received.

PB2 Trigger for pilots to check landing clearance – inclusion of an item in the landing check-list.

PB3 Trigger for pilots to check landing clearance - SOP to do so at an existing fixed point in an approach such as at a height-defined stabilisation gate.

PB4 Ensure that pilots can revert to the previous radio frequency by introducing an SOP which requires that two way contact be established on each new frequency before the pre-select frequency is changed from the previous frequency to an anticipated subsequent one.

PB5 The provision of an automatic alert to the pilot when a runway is occupied such as the visual alerting provided by the Final Approach Runway Occupancy Signal (FAROS) system (see Appendix).

PB6 Robust procedures to ensure that the correct runway and/or runway approach procedure are entered into aircraft on-board systems that require this and that the correct approach procedure is displayed to both pilots.

PB7 Pilot positive visual identification of the correct runway except in Cat 2/3 conditions.

PB8 Signs and markings to clearly indicate closed runway.

PB9 Other means for controllers to alert pilot to the absence (or existence) of a landing clearance such as the availability of a selectable visual alert illuminated close to touchdown.

PB10 The availability of an effective controller memory aid to annunciate whether landing clearances have been issued or not.

PB11 System supported ATCO detection of aircraft about to land without clearance or on the wrong runway with one, for example, ASMGCS and RIMCAS (see Appendix).

PB12 Controller visual detection of an aircraft about to land without clearance.

PB13 Controller visual detection of an aircraft about to land on a runway other than the one for which clearance has been given.

PB14 A specific go-around policy in case of pilot awareness of no landing clearance which is effectively monitored for compliance.

4.4 Barriers which may mitigate the consequences of landing without clearance

Barriers mitigating the effects of landing without clearance

MB1 Controller prevents conflict after detecting the risk of it visually before, during or after the issue of a potentially conflicting runway access clearance and before entering the runway.

MB2 Controller prevents conflict after detecting it with system support before, during or after the issue of a potentially conflicting runway access clearance and before entering the runway.

MB3 Flight crew/vehicle driver prevent conflict after detecting the risk of it from radio traffic or visual monitoring before, during or after receiving a runway access clearance and before entering the runway.

MB4 Flight crew/vehicle driver prevent conflict after detecting the risk of it with system support such as the RWSL system components Runway Entrance Lights (REL) s and Take-off Hold Lights (THLs) before or after receiving a runway access or movement clearance and before entering the runway (see Appendix).

MB5 Controller runway conflict resolution after detecting the risk visually.

MB6 Controller runway conflict resolution after detecting the risk with the help of surveillance systems.

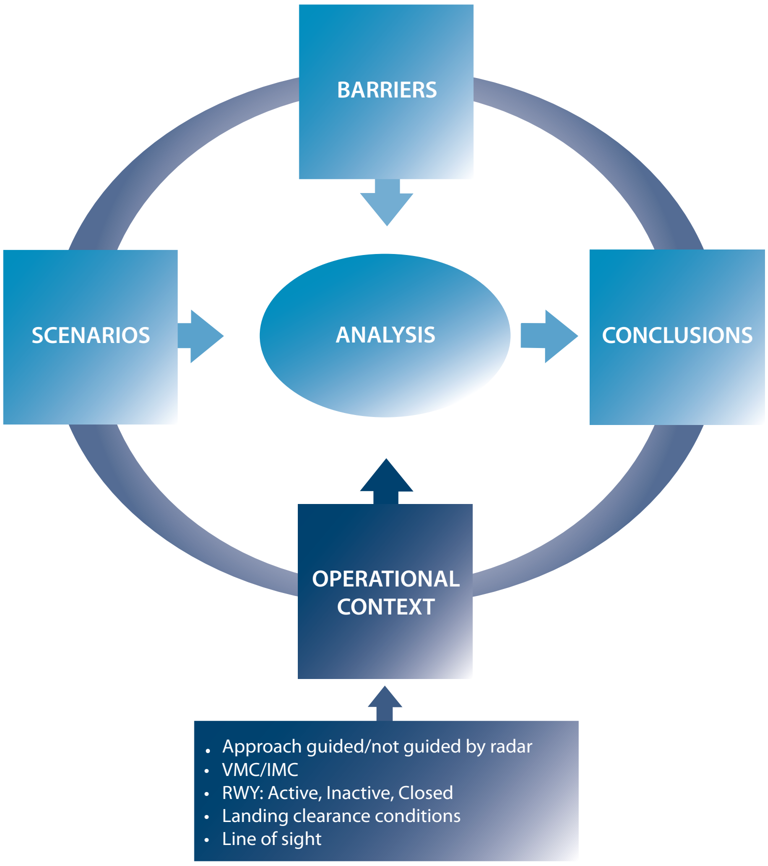
MB7 Controller runway conflict resolution after detection the risk by a safety net alert such as RIMCAS.

MB8 Flight crew/Vehicle driver runway conflict resolution after detecting the risk visually.

MB9 Flight crew/Vehicle driver runway conflict resolution after detecting the risk based on R/T traffic monitoring.

MB10 Flight crew/Vehicle driver runway conflict resolution after detecting the risk with system support.

CHAPTER 5 - OPERATIONAL CONTEXT



5.1 Different operational context

The operational context that may affect the efficiency of barriers

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

- Availability of radar guidance for the approach
- Meteorological conditions and time of the day
- Runway status
- Clearance conditions
- Visual surveillance capability from the Tower

5.2 Radar coverage

The level of ATC radar coverage may differ

Radar guided approaches affect likelihood for detecting an aircraft bound for landing and the existing situation of loss of communication when the transponder Mode A is set to squawk 7600.

5.3 Meteorological conditions

Possibility of detecting potential threats in good time

The in-flight visibility and time of the day be such as to allow pilots to:

- Recognise potential threats in good time.
- Prevent the recognition of potential threats in good time.

The surface visibility/cloud base and time of the day be such as to allow controller:

- Recognise potential threats in good time.
- Prevent the recognition of potential threats in good time.

5.4 Runway status

Runways can be in use or not for traffic purposes and there may or may not be obstructions

The runway status that can influence the efficiency of barriers for the different scenarios are:

- Active Runway
- Inactive Runway
- Closed Runway

5.5 Clearance conditions

Variation in local procedures and practices for delivering a landing clearance

The way landing clearance is delivered at different airports may vary, including whether or not:

- Multiple landing clearances are used.
- Conditional landing clearances are issued.
- There are specified minimum distances from the runway threshold (or landed/departing traffic) by which a landing clearance must be issued.

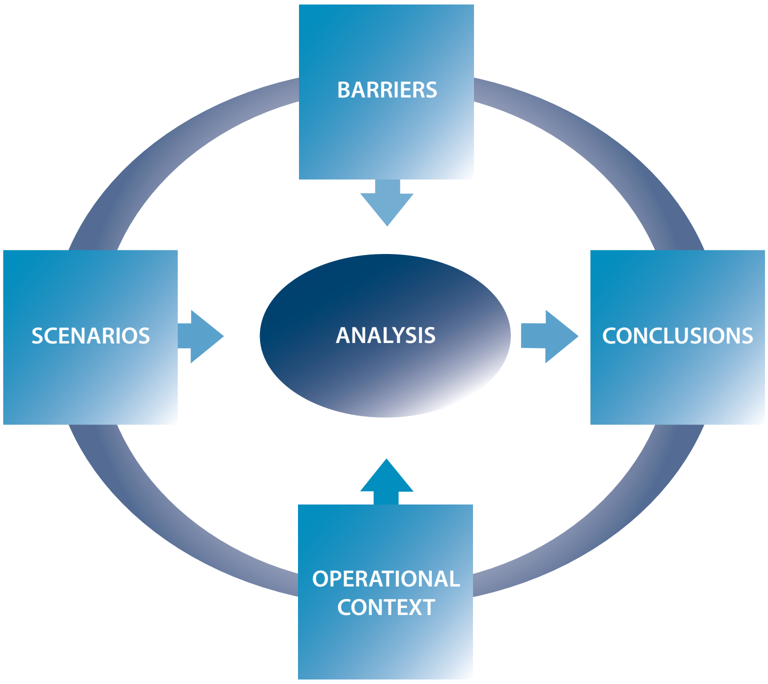
5.6 Visual surveillance capability from the TWR

Physical visibility

The view (direct or using CCTV) of the relevant part of the aerodrome and its vicinity from The ATC Tower may be restricted by:

- The location, height, design, equipment of the tower.
- The airport layout or obstructions
- The temporary presence of aircraft or vehicles.

CHAPTER 5 - ANALYSIS



6.1 Analysis of Prevention Barriers

Table 1: Analysis of Prevention Barrier Efficiency PB1-PB7[1]

OPERATIONAL SCENARIOS:	PREVENTION BARRIERS:						
	PB1: SOP for turning the landing/taxi lights on when clearance to land is received.	**PB2:** An item in the landing check-list to check.	**PB3:** SOP for a check call at a given approach point/height.	**PB4:** Pilot SOP to revert to the previous sector frequency	**PB5:** Automatic alert to the pilot for occupied runway.	**PB6:** Pilot procedures: correct runway in the systems and correct approach charts.	**PB7:** Pilot visual identification of the correct RWY.
A1: LwC after loss of comm/on an unoccupied runway when no other clearance for the runway has been given.				The barrier can support prevention of cases initiated by mistuning the radio channel if recognised.			
A2: LwC without clearance after loss of comm/on an unoccupied runway when another clearance for the runway has been given.				The barrier can support prevention of cases initiated by mistuning the radio channel if recognised.			
A3: LwC after loss of comm. on an occupied runway.				The barrier can support prevention of cases initiated by mistuning the radio channel if recognised.			
B1: LwC after runway confusion on an unoccupied runway when no other clearance for the runway has been given.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.				Depends on the inflight visibility
B2: LwC after runway confusion on an unoccupied runway when another clearance for the runway has been given.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.				Depends on the inflight visibility
B3: LwC after runway confusion on an occupied runway.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.	The barrier can support prevention of cases where the runway is correctly identified but there is confusion about the clearance received.				Depends on the inflight visibility

[1] Note: Red shading defines either an inefficient barrier or barrier that is not intended for the operational scenario, yellow shading defines barrier that is partially effective or partially efficient for the operational scenario or efficient under certain conditions, and green shading defines barrier that is effective and efficient for the operational scenario.

OPERATIONAL SCENARIOS:	PREVENTION BARRIERS:						
	PB1: SOP for turning the landing/taxi lights on when clearance to land is received.	**PB2:** An item in the landing check-list to check.	**PB3:** SOP for a check call at a given approach point/height.	**PB4:** Pilot SOP to revert to the previous sector frequency	**PB5:** Automatic alert to the pilot for occupied runway.	**PB6:** Pilot procedures: correct runway in the systems and correct approach charts.	**PB7:** Pilot visual identification of the correct RWY.
C1: LwC after communication misunderstanding on an unoccupied runway when no other clearance for the runway has been given.							
C2: LwC after communication misunderstanding on an unoccupied runway when another clearance for the runway has been given.							
C3: LwC after loss of comm. on an occupied runway.							
D1: LwC after the absence of clearance was overlooked on an unoccupied runway when no other clearance for the runway has been given.	This barrier depends on a passive, rather than actively enunciated, trigger.	Active trigger but effectiveness depends on the timing of landing check-list completion.	Active trigger - guaranteed prompt				
D2: LwC after the absence of clearance was overlooked on an unoccupied runway when another clearance for the runway has been given.	This barrier depends on a passive, rather than actively enunciated, trigger.	Active trigger but effectiveness depends on the timing of landing check-list completion.					
D3: LwC after the absence of clearance was overlooked on an occupied runway.	This barrier depends on a passive, rather than actively enunciated, trigger.	Active trigger but effectiveness depends on the timing of landing check-list completion.					

OPERATIONAL SCENARIOS:	PREVENTION BARRIERS:						
	PB1: SOP for turning the landing/taxi lights on when clearance to land is received.	**PB2:** An item in the landing check-list to check.	**PB3:** SOP for a check call at a given approach point/height.	**PB4:** Pilot SOP to revert to the previous sector frequency	**PB5:** Automatic alert to the pilot for occupied runway.	**PB6:** Pilot procedures: correct runway in the systems and correct approach charts.	**PB7:** Pilot visual identification of the correct RWY.
E1: Deliberate LwC on an unoccupied runway when no other clearance for the runway has been given.							
E2: Deliberate LwC on an unoccupied runway when another clearance for the runway has been given.							
E3: Deliberate LwC on an occupied runway.							

Table 2: Analysis of Prevention Barrier Efficiency PB8-PB14

OPERATIONAL SCENARIOS:	PREVENTION BARRIERS:						
	PB8: Signs and markings to clearly indicate closed RWYs.	**PB9:** Other alert to the pilot via ATC for lack of landing clearance e.g. -visual alerts.	**PB10:** ATCO memory aid for issued landing clearances.	**PB11:** System supported ATCO detection of landing aircraft or of potential conflict for the landing aircraft	**PB12:** ATCO visual detection of landing a/c.	**PB13:** ATCO visual detection of lan-ding a/c on correct/ incorrect RWY.	**PB14:** Go-around policy conditions in case of no landing clearance.
A1: LwC after loss of communication on an unoccupied runway when no other clearance for the runway has been given .	Poor visibility may reduce the effectiveness of this barrier.	ATC would normally permit landing.					Pilots expected to follow loss of comms procedures.
A2: LwC after loss of communication on an unoccupied runway when another clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.						Pilots expected to follow loss of comms procedures.
A3: LwC after loss of communication on an occupied runway.	Poor visibility may reduce the effectiveness of this barrier.						Pilots expected to follow loss of comms procedures.

OPERATIONAL SCENARIOS:	PREVENTION BARRIERS:						
	PB8: Signs and markings to clearly indicate closed RWYs.	**PB9:** Other alert to the pilot via ATC for lack of landing clearance e.g. -visual alerts.	**PB10:** ATCO memory aid for issued landing clearances.	**PB11:** System supported ATCO detection of landing aircraft or of potential conflict for the landing aircraft	**PB12:** ATCO visual detection of landing a/c.	**PB13:** ATCO visual detection of lan-ding a/c on correct/ incorrect RWY.	**PB14:** Go-around policy conditions in case of no landing clearance.
B1: LwC after runway confusion on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	ATC would normally permit landing.	This barrier depends on no clearance being given for any runway.		Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends on no clearance being given for any runway.
B2: LwC after runway confusion on an unoccupied runway when another clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	ATC would normally permit landing	This barrier depends on no clearance being given for any runway.		Poor visibility may reduce the effectiveness of this barrier.	This barrier depends upon good visibility.	This barrier depends on no clearance being given for any runway.
B3: LwC after runway confusion on an occupied runway.	Poor visibility may reduce the effectiveness of this barrier.		This barrier depends on no clearance being given for any runway.		Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends on no clearance being given for any runway.
C1: LwC after communication misunderstanding on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	ATC would normally permit landing.			Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends on no clearance being given for any runway.
C2: LwC after communication misunderstanding on an unoccupied runway when another clearance for the runway has been given.	This barrier depends upon good visibility.				Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	
C3: LwC after communication misunderstanding on an occupied runway.	Poor visibility may reduce the effectiveness of this barrier.				Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	

OPERATIONAL SCENARIOS:	**PREVENTION BARRIERS:**						
	PB8: Signs and markings to clearly indicate closed RWYs.	**PB9:** Other alert to the pilot via ATC for lack of landing clearance e.g. -visual alerts.	**PB10:** ATCO memory aid for issued landing clearances.	**PB11:** System supported ATCO detection of landing aircraft or of potential conflict for the landing aircraft	**PB12:** ATCO visual detection of landing a/c.	**PB13:** ATCO visual detection of lan-ding a/c on correct/ incorrect RWY.	**PB14:** Go-around policy conditions in case of no landing clearance.
D1: LwC after the absence of clearance was overlooked on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.				Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	
D2: LwC after the absence of clearance was overlooked on an unoccupied runway when another clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	ATC would normally permit landing			Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	
D3: LwC after the absence of clearance was overlooked on an occupied runway.	Poor visibility may reduce the effectiveness of this barrier.				Poor visibility may reduce the effectiveness of this barrier.	Poor visibility may reduce the effectiveness of this barrier.	
E1: Deliberate LwC on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends upon detail of technical fix.					
E2: Deliberate LwC on an unoccupied runway when another clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends upon detail of technical fix.					
E3: Deliberate LwC on an occupied runway.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends upon detail of technical fix.					

6.2 Analysis of Mitigation Barriers

Table 3: Analysis of Mitigation Barrier Efficiency MB1-MB5[2]

OPERATIONAL SCENARIOS:	MITIGATION BARRIERS:				
	MB1: ATCO prevents conflict after detecting it visually before or with an intended RWY entry clearance.	**MB2:** ATCO prevents conflict after detecting it with system support before or with an intended RWY entry clearance.	**MB3:** Crew/driver prevents conflict after detecting it, based on traffic monitoring, before or with an intended RWY entry clearance.	**MB4:** Crew/driver prevents conflict after detecting it with system support before or with an intended RWY entry clearance.	**MB5:** ATCO RWY conflict resolution after detecting it visually.
A1: LwC after loss of communication on an unoccupied runway when no other clearance for the runway has been given			No Conflict	No Conflict	No Conflict
A2: LwC after loss of communication on an unoccupied runway when another clearance for the runway has been given.			No communications and limited visual observation of the landing traffic		Resolution via other party
A3: LwC after loss of communication on an occupied runway.			No communications and limited visual observation of the landing traffic		Resolution via other party
B1: LwC after runway confusion on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.		No Conflict	No Conflict	No Conflict
B2: LwC after runway confusion on an unoccupied runway when another clearance for the runway has been given.					Poor visibility may reduce the effectiveness of this barrier.
B3: LwC after runway confusion on an occupied runway.			Poor visibility may reduce the effectiveness of this barrier.		Poor visibility may reduce the effectiveness of this barrier.
C1: LwC after communication misunderstanding on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.		No Conflict	No Conflict	No Conflict
C2: LwC after communication misunderstanding on an unoccupied runway when another clearance for the runway has been given.			Poor visibility may reduce the effectiveness of this barrier.		Poor visibility may reduce the effectiveness of this barrier.
C3: LwC after communication misunderstanding on an occupied runway.			Poor visibility may reduce the effectiveness of this barrier.		Poor visibility may reduce the effectiveness of this barrier.

2 Note: Additionally to the already defines shadings, grey shading defines a barrier that is not challenged by the scenario.

OPERATIONAL SCENARIOS:	MITIGATION BARRIERS:				
	MB1: ATCO prevents conflict after detecting it visually before or with an intended RWY entry clearance.	**MB2:** ATCO prevents conflict after detecting it with system support before or with an intended RWY entry clearance.	**MB3:** Crew/driver prevents conflict after detecting it, based on traffic monitoring, before or with an intended RWY entry clearance.	**MB4:** Crew/driver prevents conflict after detecting it with system support before or with an intended RWY entry clearance.	**MB5:** ATCO RWY conflict resolution after detecting it visually.
D1: LwC after the absence of clearance was overlooked on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.		No Conflict	No Conflict	No Conflict
D2: LwC after the absence of clearance was overlooked on an unoccupied runway when another clearance for the runway has been given.			Poor visibility may reduce the effectiveness of this barrier.		Poor visibility may reduce the effectiveness of this barrier.
D3: LwC after the absence of clearance was overlooked on an occupied runway.			Poor visibility may reduce the effectiveness of this barrier.		Poor visibility may reduce the effectiveness of this barrier.
E1: Deliberate LwC on an unoccupied runway when no other clearance for the runway has been given.	Poor visibility may reduce the effectiveness of this barrier.	This barrier depends upon reason for deliberate act – judgemental or non-conformance	No Conflict	No Conflict	No Conflict
E2: Deliberate LwC on an unoccupied runway when another clearance for the runway has been given.		This barrier depends upon reason for deliberate act – judgemental or non-conformance			Poor visibility may reduce the effectiveness of this barrier.
E3: Deliberate LwC on an occupied runway.		This barrier depends upon reason for deliberate act – judgemental or non-conformance			Poor visibility may reduce the effectiveness of this barrier.

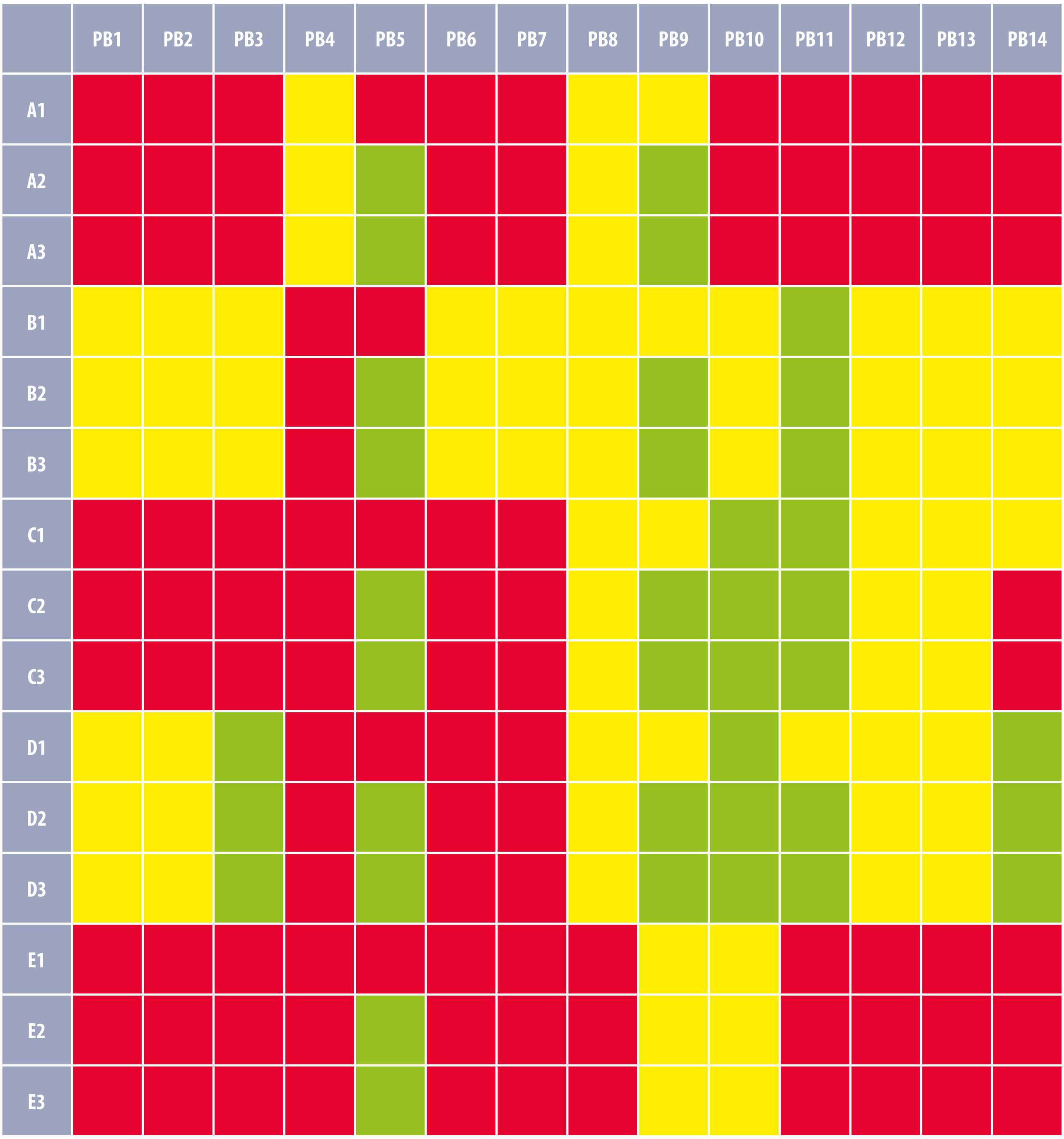
Table 4: Analysis of Mitigation Barrier Efficiency MB6-MB10

OPERATIONAL SCENARIOS:	MITIGATION BARRIERS:				
	MB6: ATCO RWY conflict resolution after detecting it with the help of surveillance.	**MB7:** ATCO RWY conflict resolution after detecting it with safety net.	**MB8:** Pilot/Driver RWY conflict resolution after detecting it visually.	**MB9:** Pilot/Driver RWY conflict resolution after detecting it based on R/T traffic monitoring.	**MB10:** Pilot/Driver RWY conflict resolution after detecting it with system support.
A1: LwC after loss of communication on an unoccupied runway when no other clearance for the runway has been given	No Conflict	No Conflict	No Conflict	No Conflict	No Conflict
A2: LwC after loss of communication on an unoccupied runway when another clearance for the runway has been given.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		Resolution via other party
A3: LwC after loss of communication on an occupied runway.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		
B1: LwC after runway confusion on an unoccupied runway when no other clearance for the runway has been given.	No Conflict	No Conflict	No Conflict	No Conflict	No Conflict
B2: LwC after runway confusion on an unoccupied runway when another clearance for the runway has been given.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		
B3: LwC after runway confusion on an occupied runway.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		
C1: LwC after communication misunderstanding on an unoccupied runway when no other clearance for the runway has been given.	No Conflict	No Conflict	No Conflict	No Conflict	No Conflict
C2: LwC after communication misunderstanding on an unoccupied runway when another clearance for the runway has been given.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		
C3: LwC after communication misunderstanding on an occupied runway.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		

OPERATIONAL SCENARIOS:	MITIGATION BARRIERS:				
	MB6: ATCO RWY conflict resolution after detecting it with the help of surveillance.	**MB7:** ATCO RWY conflict resolution after detecting it with safety net.	**MB8:** Pilot/Driver RWY conflict resolution after detecting it visually.	**MB9:** Pilot/Driver RWY conflict resolution after detecting it based on R/T traffic monitoring.	**MB10:** Pilot/Driver RWY conflict resolution after detecting it with system support.
D1: LwC after the absence of clearance was overlooked on an unoccupied runway when no other clearance for the runway has been given.	No Conflict	No Conflict	No Conflict	No Conflict	No Conflict
D2: LwC after the absence of clearance was overlooked on an unoccupied runway when another clearance for the runway has been given.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		Depends on a system that recognises runway occupancy without authorisation
D3: LwC after the absence of clearance was overlooked on an occupied runway.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		
E1: Deliberate LwC on an unoccupied runway when no other clearance for the runway has been given.	No Conflict	No Conflict	No Conflict	No Conflict	No Conflict
E2: Deliberate LwC on an unoccupied runway when another clearance for the runway has been given.	Depends upon time and actions available to resolve.	Depends upon time and actions available to resolve.	Poor visibility may reduce the effectiveness of this barrier.		
E3: Deliberate LwC on an occupied runway.			Poor visibility may reduce the effectiveness of this barrier.		

6.3 Prevention Barrier Matrix

Table 5: Prevention Barrier Matrix



6.4 Top 4 Potential Prevention Barriers

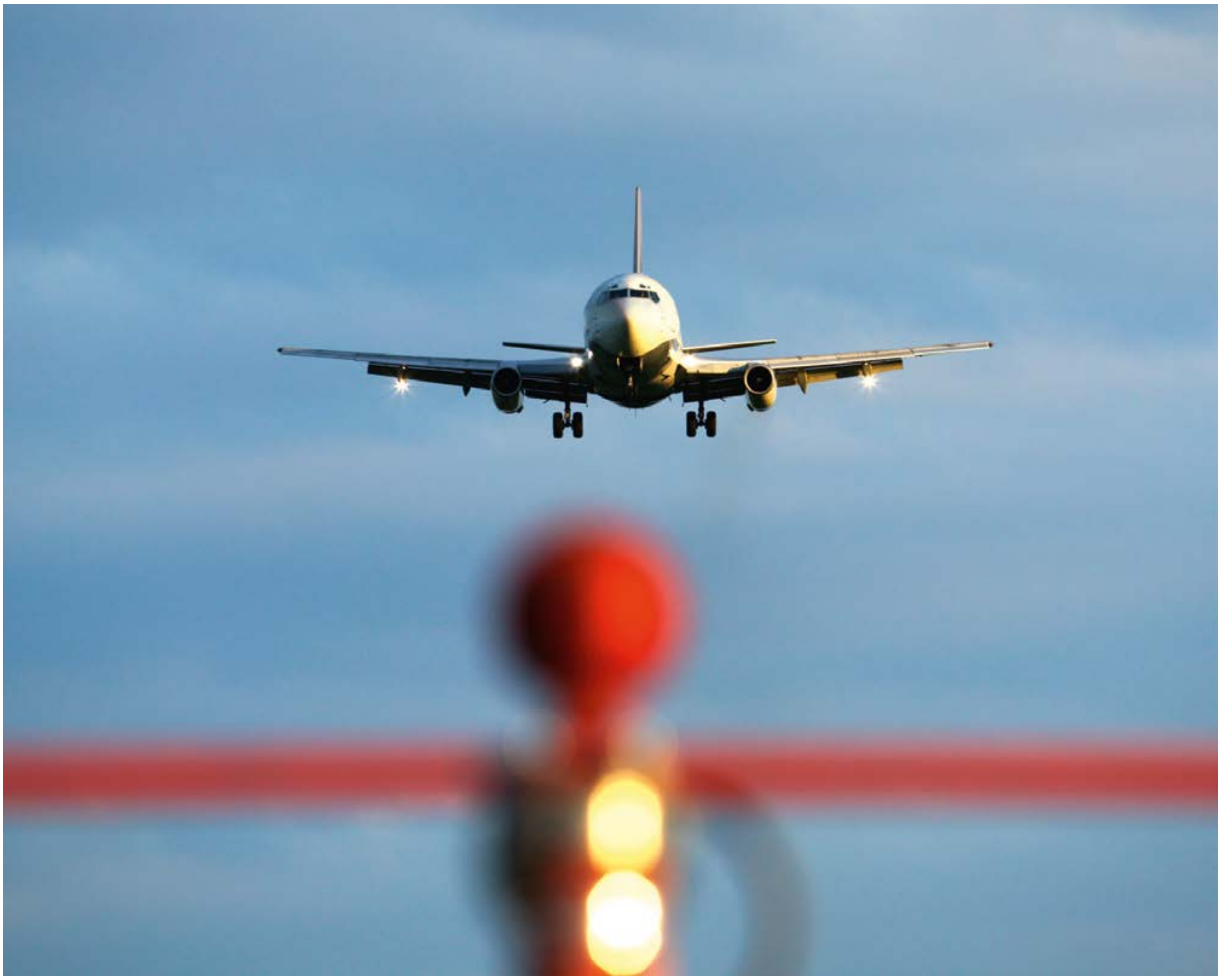
PB5 has the highest number of Green (always) responses; however PB9 has the highest combined Green/Yellow (always/sometimes) rate.

PB9 Other alert to the pilot via ATC for lack of landing clearance e.g. selection of visual alert.

PB5 Automatic alert to the pilot for occupied runway (for example visual alert in the case of Final Approach Runway Status Signal type of Runway Status Lights.

PB11 System supported ATCO detection of landing aircraft or of potential conflict for the landing aircraft (for example ASMGCS and RIMCAS).

PB10 ATCO memory aid for issued (not issued) landing clearances (strips, flight data).



6.5 Mitigation Barrier Matrix

Table 6: Mitigation Barrier Matrix

	PB1	PB2	PB3	PB4	PB5	PB6	PB7	PB8	PB9	PB10
A1										
A2										
A3										
B1										
B2										
B3										
C1										
C2										
C3										
D1										
D2										
D3										
E1										
E2										
E3										

6.6 Top 4 Potential Mitigation Barriers

MB2 has the highest rate, followed by MB10.

MB2 ATCO prevents conflict after detecting it with system support before or with an intended RWY entry clearance.

MB10 Flight crew/Vehicle driver runway conflict resolution after detecting the risk with system support. This is in fact an airborne safety net to help flight crew in identification and resolution of runway conflicts.

MB3 Crew/driver prevents conflict after detecting it, based on traffic monitoring (listening to R/T or visually), before or with an intended RWY entry clearance. This barrier relatively weak but is selected to be part of the top 4 mitigation barriers because of the 'double' opportunity for conflict detection – visual and listening to the R/T.

MB8 Pilot/Driver RWY conflict resolution after detecting it visually. This barrier is relatively weak but is selected to be part of the top 4 mitigation barriers because of the limited delay (no need of an ATC-crew communication loop) for crew action in case of conflict detection.

CHAPTER 7 - OTHER STUDIES

7.1 MIT Lincoln Laboratory

FAA occurrence data documents a total of 1369 runway incursions in the USA between 1997 and 2000. An average of one runway incursion every day. MIT Lincoln Laboratory carried out a study of the 167 most high risk events (defined as an actual miss distance of less than 100 feet at speeds likely to cause major damage and loss of life). Approximately 20% of events were deemed to be not time-critical whereby ATC has sufficient time to effect a resolution. 80% of events however were time-critical with resolution best dealt with in the pilot domain.

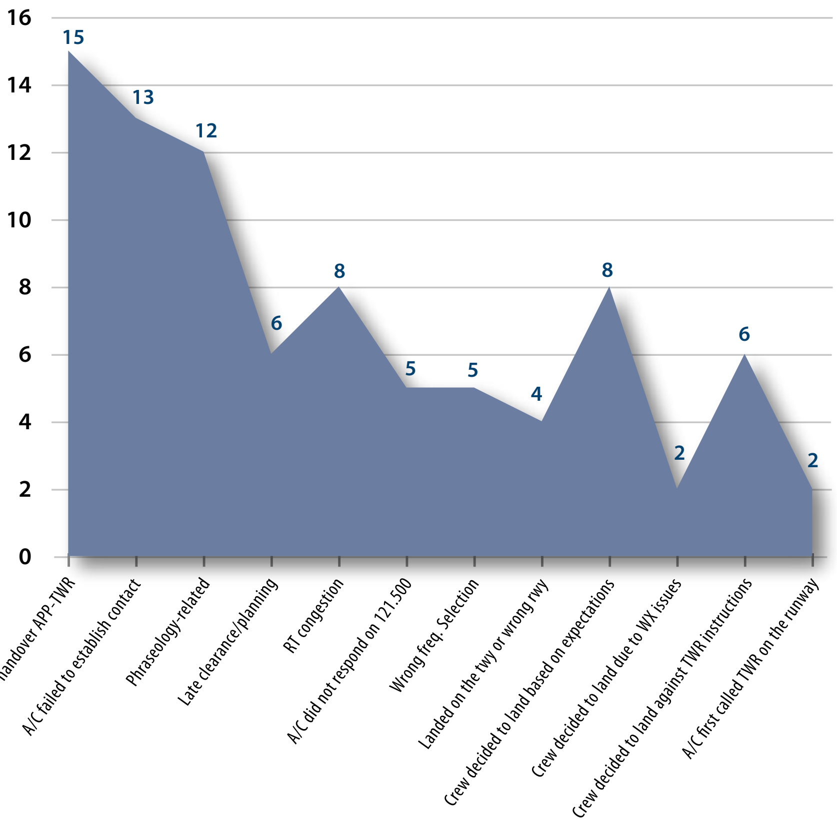
A comprehensive review of incursion geometries revealed that the combined use of runway entrance lights and takeoff hold lights in a runway status light system would provide a warning to one or both of the affected pilots in about 65% of the cases studied. Status lights in conjunction with ATC based systems would address about 85% of all incursions.

7.2 AENA

A recent study by AENA "To land or not to land" reviewed a total of 66 events globally between 2007 and 2012 i.e. an average of 11 per year.

The study found that Communication was the principal grouping of contributory factors.

- 15 events (23%) there was no handover of the aircraft from Approach to Tower
- 13 events (20%) the aircraft failed to establish contact with Tower
- 12 events (18%) involved misunderstandings in phraseology.
- 5 events (8%) involved miss-selection of the frequency



It was noted that the failure to transfer an aircraft from Approach Control to Aerodrome Control opens a wide window of opportunity for other factors to intervene, with negative safety consequences.

On many occasions the aircraft did not call Tower, even if correctly instructed to do so. Attentional issues and crew task workload were mainly identified as well as the fact that there is no specific "landing clearance confirmation" bullet built into pre-landing checklists.

7.3 NASA

heryl L. Chappell, NASA Aviation Safety Reporting System, published a study in 1994 "Lessons Learned from Landings without a Clearance"

There are a great number of reports into NASA's Aviation Safety Reporting System (ASRS) that identify pilots' failure to obtain clearances prior to landing. A small number (37) of ASRS reports of landings without clearances were looked at in depth and revealed some patterns.

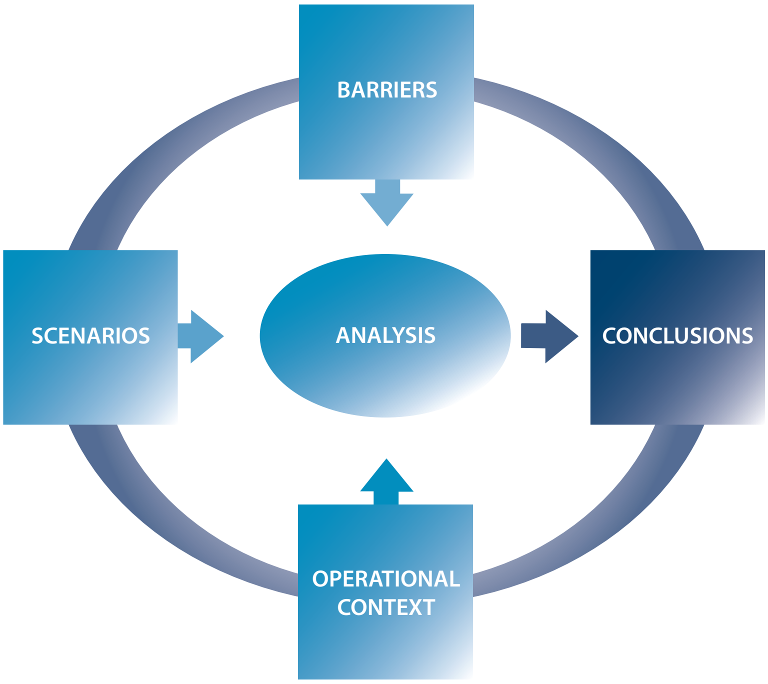
Not on tower frequency.
Of the 34 reports mentioning the frequency pilots were on when they landed, 74% of them were on Approach frequency and only 24% were on tower. Of the 8 reporters who did change to Tower frequency, 5 made initial contact with the tower but did not receive landing clearance.

Lack of clearance discovered too late.
62% of the pilots did finally notice they had not received a clearance, albeit too late. They generally detected their error either while they were still on the runway (7) or as they were turning off the runway and changing to ground frequency (10). This latter finding suggests that if there is a fixed point in cockpit procedures where pilots consistently change frequencies, they may be more likely to remember to do so.

High workload.
95% of the 37 reporters stated that their workload was high during approach. They felt that the many other things going on contributed to their not getting landing clearance.
The reporters' sources of workload were varied. Some pilots were in a training situation, some were busy due to weather conditions.

Forgetting to call tower at the marker (approximately 4 DME).
A pattern in the 37 reports was the likelihood of a pilots forgetting to contact the tower if they were told to do so too far in advance. 9 reporters indicated they were told to contact the tower at the marker, sometimes as far as 20 miles out. 7 of these never switched to tower frequency.

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS



Conclusion 1	This study has identified the four potential prevention barriers and the fourm potential mitigation barriers that could, if implemented and applied, achieve the highest safety gain.
Conclusion 2	The three external studies referenced in this paper all support the advancement of the Top 4 barriers identified. They also however suggest that safety gains could be achieved by further refinement and development of some other barriers; notably barriers that would reduce the occurrence of pilots that are not in communication with Aerodrome Control.
Conclusion 3	**Prevention Barrier PB9:** Alert to pilot via ATC for lack of landing clearance. ATC could have a manually selectable warning tool. This, combined with an SOP to go around on observing the alert, could be an effective and low cost barrier.
Recommendation 1	**It is recommended that European Stakeholders jointly perform Feasibility and Options studies to optimise the preventative barrier - Alert to pilot via ATC for lack of landing clearance.**
Conclusion 4	**Prevention Barrier PB5:** Automatic alert to the pilot for occupied runway (for example visual alert in the case of Final Approach Runway Status Signal type of Runway Status Lights system). This barrier will not prevent the relatively benign landing without clearance event, where there is no immediate conflicting traffic. The study by Lincoln however suggests that up to 65% of serious events could be prevented by the implementation of such a system. The FAA is sponsoring the deployment of the FAROS system in the USA.
Recommendation 2	**It is recommended that European stakeholders monitor the implementation and effectiveness of the FAROS system in the USA to inform their safety improvement plans.**
Conclusion 5	**Prevention Barrier PB11:** System supported ATCO detection of landing aircraft or of potential conflict for the landing aircraft (for example ASMGCS and RIMCAS). These systems have the potential to assist in the prevention of majority Landing without Clearance events. They are however dependent upon ATCO participation. The ATCO has to be alert to the system warning, correctly assimilate the information and take corrective action, all within a short time span. The MIT Lincoln Laboratory study suggests that a combination of Runway Status Lighting and System supported ATCO detection could prevent up to 85% of runway incursions.
Conclusion 6	**Prevention Barrier PB10:** SATCO memory aid for issued (not issued) landing clearances (strips, flight data). The AENA study suggests that ineffective ATC and internal handovers between Approach control and Aerodrome control was a factor in 34% of events. The NASA study suggests that this rate of occurrence is even higher. Therefore there is evidence that strengthening the effectiveness of the ATC barrier could underpin a safety gain.

Recommendation 3	**ANSPs should share industry best practice in the management of transfer of communication and the management of flight data displays and memory aids.**
Conclusion 7	**Mitigation Barrier MB2:** ATCO prevents conflict after detecting it with system support (e.g. ASMGCS) before or with an intended RWY entry clearance. This appears to be a very strong Mitigation barrier as the ATCO has the information available to prevent the runway confliction. It does however have the same dependencies upon the same as PB11, but kicks in later in the event chain.
Recommendation 4	**ANSPs should accelerate their runway safety nets implementation plans in the cases where they are considered economically viable.**
Conclusion 8	**Mitigation Barrier MB10:** Flight crew/Vehicle driver runway conflict resolution after detecting the risk with system support. This is in fact an airborne safety net to help flight crew in identification and resolution of runway conflict. This barrier depends on the aircraft equipage.
Conclusion 9	**Mitigation Barrier MB3:** Crew/driver prevents conflict after detecting it, based on traffic monitoring (listening to R/T or visually), before or with an intended RWY entry clearance. This barrier has dependencies concerning correct R/T communication, good visibility and good airside awareness training.
Recommendation 5	**Airport operations stakeholders review Airside driver training to ensure that instruction is given on proactive safety procedures around active runways, which could include the sharing of past event examples.**
Conclusion 10	**Mitigation Barrier MB8:** Pilot/Driver RWY conflict resolution after detecting it visually. This barrier is dependent upon good visibility. This mitigation barrier is also addressed by the previous recommendation.

APPENDIX A - SAFETY NETS

1. **Final Approach Runway Occupancy Signal (FAROS)**
2. **Runway Status Lights (RWSL)**
3. **Advanced Surface Movement Guidance & Control System (ASMGCS)**
4. **Runway Awareness and Advisory System (RAAS)**
5. **Enhanced Vision System (EVS)**

1. Final Approach Runway Occupancy Signal (FAROS)

Final Approach Runway Occupancy Signal (**FAROS**) is an FAA-sponsored concept, which is now being deployed for operational evaluation in the USA.

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.

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. The **FAROS** system is provided to enhance pilot awareness only. It does not substitute for, or interfere with, existing ATC authority or flight crew procedures, and activation does not affect the validity of an existing ATC Landing Clearance. In many cases, it may be activated on short finals as another aircraft departs from the same runway or an aircraft or vehicle cross it in accordance with their ATC clearances.

2. Runway Status Lights (RWSL)

As developed and deployed at major airports in the USA, a RWSL system is a fully automatic advisory safety system which provides direct alerts to both vehicles and pilots independently of the normal traffic control system operated by ATC. Early versions of the system had two elements, Runway Entrance Lights (RELs) and Take-Off Hold lights (THLs). Runway Intersection Lights (RHLs) were subsequently added and now the intention is to integrate the three RWSL elements with the Final Approach Runway Occupancy Signal (FAROS) system.

A graphic of showing a typical application of the three 'baseline; elements of the system is shown below. In summary, the principles are that:

- **RELs** warn that it is unsafe to enter/cross a runway
- **THLs** warn that it is unsafe to take off from a runway
- **RILs** warn that it is unsafe to cross a runway intersection

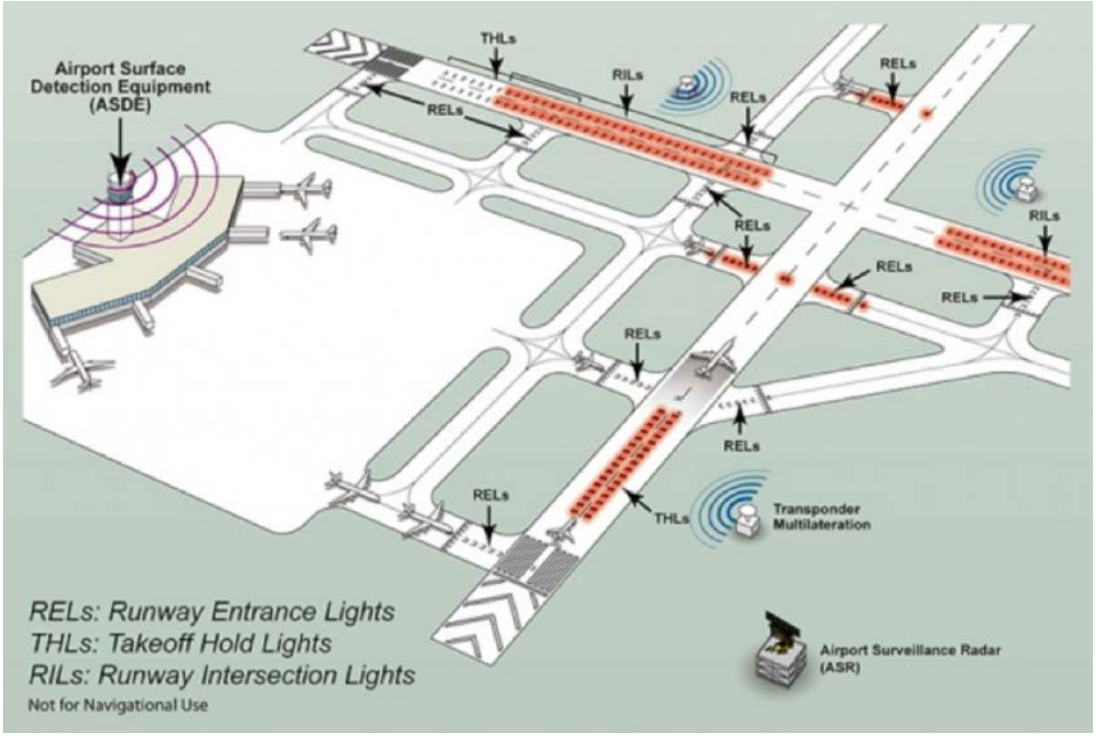
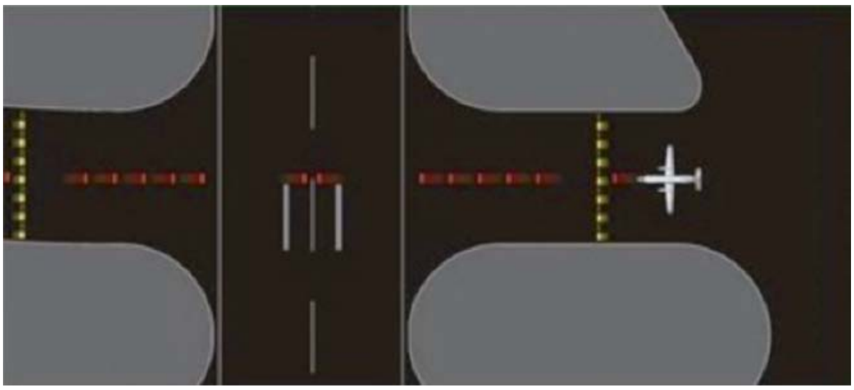


Diagram prepared by MIT Lincoln Laboratory

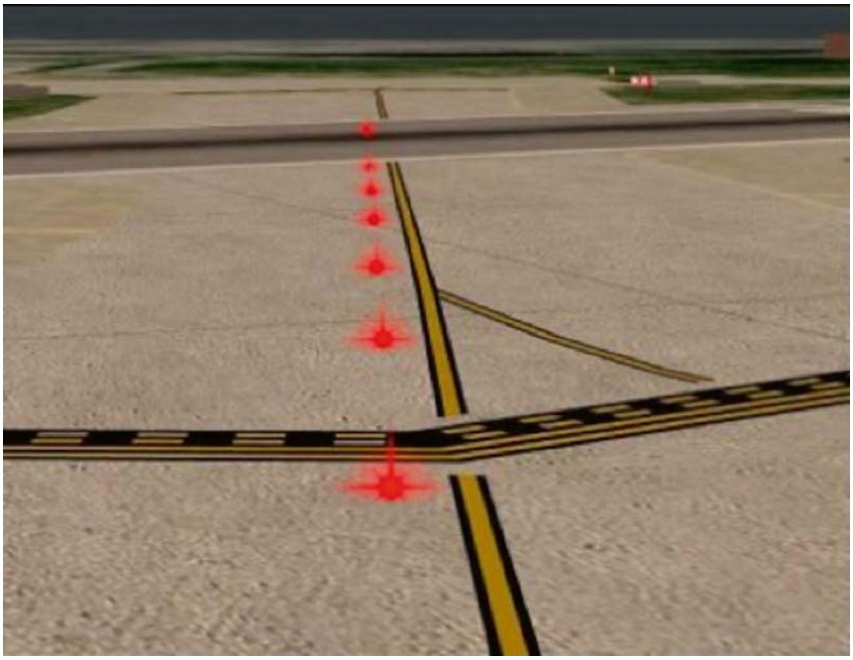
It is important to note that activation of RWSL components is completely independent of ATC clearances and their activation as a backup safety net against human error bears no relation to the presence or absence of an ATC clearance. However, when RWSL indications contradict clearances, pilots and vehicle drivers are expected to prioritize response to the status lights. Conversely, the absence of RWSL indications does not equate to an ATC clearance to proceed. It is routine to see these indications cycling between illuminated and extinguished as the relative disposition of traffic changes.

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.



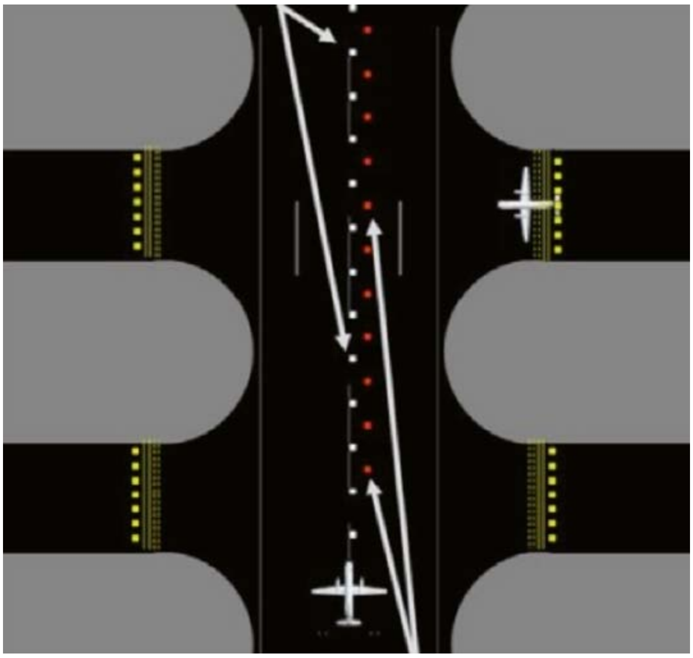
Illuminated RELs as seen from above



Pilot view of illuminated RELs

Take Off Hold Lights (THLs)

THLs are used at the runway departure area and provide an indication to pilots and vehicle drivers that the runway is unsafe for takeoff. 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.



Take off Hold Lights from above

Pilot view of Take-off Hold Lights

Runway Intersection Lights (RILs)

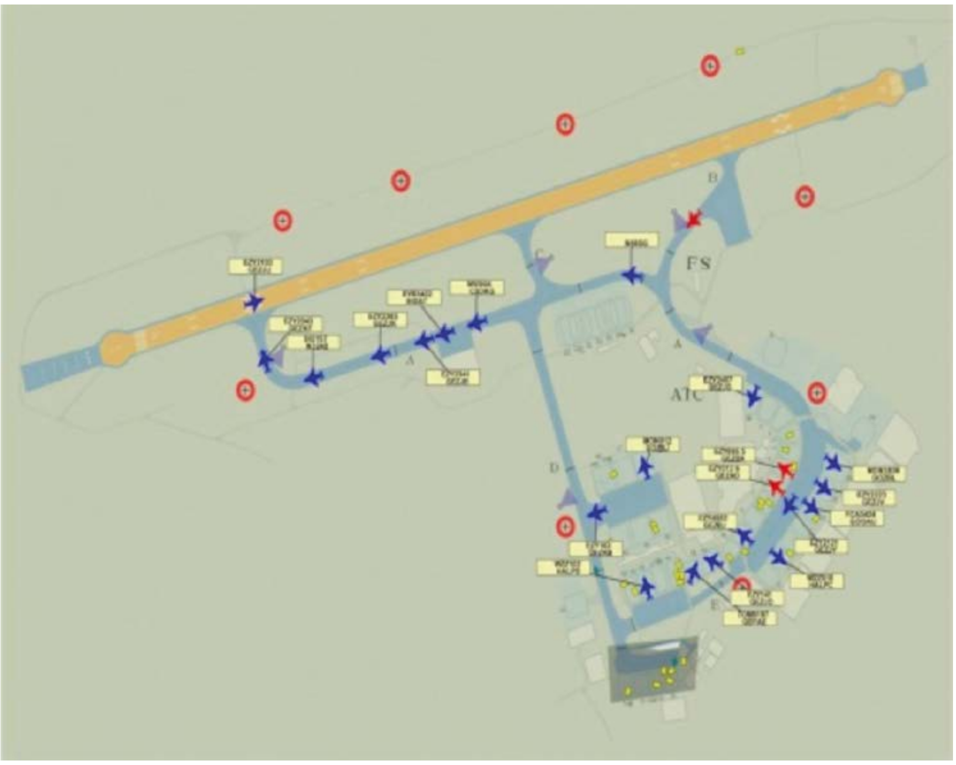
RILs are the third component of the RWSL system. They are used where one runway intersects another and provide an indication to pilots and vehicle drivers that there is high speed traffic on the intersecting runway and that it is unsafe for to enter or cross. They consist of red unidirectional lights installed in a double longitudinal row aligned with and offset to either side of the runway centreline lighting in the same manner as and using the same light fixtures as THLs.

Pilot view of Runway Intersection Lights

3. Advanced Surface Movement Guidance & Control System (ASMGCS)

A-SMGCS is a system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety. (ICAO Doc 9830: Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual)

A-SMGCS is a modular system consisting of different functionalities to support the safe, orderly and expeditious movement of aircraft and vehicles on aerodromes under all circumstances with respect to traffic density and complexity of aerodrome layout, taking into account the demanded capacity under various visibility conditions.



A-SMGCS is more than just a set of systems, it also includes complementary procedures and at the lower levels of implementation aims to deliver improved situational awareness to controllers. Higher levels of implementation deliver safety nets, conflict detection and resolution as well as planning and guidance information for pilots and controllers.

Implementation of A-SMGCS defines 4 levels:

- **A-SMGCS Level 1** (improved Surveillance) makes use of improved surveillance and procedures, covering the manoeuvring area for ground vehicles and the movement area for aircraft. The procedures concern identification and the issuance of ATC instructions and clearances. The controllers are given traffic position and identity information which is an important step forward from the traditional **Surface Movement Radar** (SMR) image.

- **A-SMGCS Level 2** (Surveillance + **Safety Nets**) adds safety nets which protect runways and designated areas and the associated procedures. Appropriate alerts are generated for the controllers in case of conflicts between all vehicles on runways and the **incursion of aircraft** onto designated restricted areas.

- **A-SMGCS Level 3** (Conflict Detection) involves the detection of all conflicts on the movement area as well as improved guidance and planning for use by controllers.

- **A-SMGCS Level 4** (Conflict Resolution, Automatic Planning & Guidance) provides resolutions for all conflicts and automatic planning and automatic guidance for the pilots as well as the controllers.

4. Runway Awareness and Advisory System (RAAS)

The Runway Awareness and Advisory System (RAAS) is one of a number of related software enhancements available on later-model Enhanced Ground Proximity Warning Systems. RAAS is designed to improve flight crew situational awareness, thereby reducing the risks of runway incursion, runway confusion and runway excursions.

Runway Awareness and Advisory System uses airport data stored in the EGPWS database, coupled with GPS and other onboard 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 takeoff: 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. On approach and after touchdown, the system continues to announce the distance to go until the end of the runway is reached.

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.

RAAS provides the flight crew with five 'routine advisories'. Three of these annunciations will be heard by the crew in normal operations, providing increased position awareness relative to the runway during taxi and flight operations. They are intended to reduce the risk of a runway incursion. The two remaining 'routine' advisories provide information about the aircraft location along the runway, and are intended to reduce the risk of overruns. These advisories are:

- **Approaching Runway -** (In Air advisory provides the crew with awareness of which runway the aircraft is lined up with on approach.

- **Approaching Runway -** 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 of which runway the aircraft is lined-up with.

- **Distance Remaining** advisories enhance crew awareness of aircraft along-track position relative to the runway end.

- **Runway End** advisory is intended to improve flight crew awareness of the position of the aircraft relative to the runway end during low visibility conditions.

In addition, RAAS provides the flight crew with several 'non-routine' advisories/cautions. These annunciations are designed to enhance safety and situational awareness in specific situations not routinely encountered during normal aircraft operations. Some of the RAAS advisories include distance information. The unit of measure used for distance can be configured to be either metres or feet.

- **Approaching Short Runway -** In-Air advisory provides the crew with awareness of which runway the aircraft is lined-up with, and that the runway length available may be marginal for normal landing operations. If desired, an additional caution annunciation can be enabled which provides the crew with awareness that the issue has not been resolved when the aircraft is on final approach.

- **Insufficient Runway Length -** On-Ground Advisory provides the crew with awareness of which runway the aircraft is lined-up with, and that the runway length available for takeoff is less than the defined minimum takeoff runway length. If desired, an additional caution annunciation can be enabled which provides the crew with awareness that the issue has not been resolved when the aircraft is on the final stage of takeoff.

- **Extended Holding on Runway** advisory provides crew awareness of an extended holding period on the runway.
- **Taxiway Take-Off** advisory enhances crew awareness of excessive taxi speeds or an inadvertent take-off on a taxiway. If desired, this function can provide a caution annunciation in lieu of an advisory annunciation.
- **Distance Remaining** advisories provides the flight crew with position awareness during a **Rejected Take Off** (RTO).
- **Taxiway Landing** alert provides the crew with awareness that the aircraft is not lined up with a runway at low altitudes.

Each RAAS function is independently enabled based on a customer specification and when enabled, the RAAS functions operate automatically without any action required from the flight crew.

In addition to the aural annunciations provided, visual annunciations can be activated in the form of caution indications if the annunciations are considered cautions. Visual text annunciations can also be configured to be overlaid on the terrain display for a period of time when the condition is entered.

5. Enhanced Vision System (EVS)

Enhanced Vision is a technology which incorporates information from aircraft based sensors (e.g., near-infrared cameras, millimeter wave radar) to provide vision in limited visibility environments.

EVS II systems use an IR camera mounted in the aircraft's nose to project a raster image on the Heads-Up Display (**HUD**). The IR image on the HUD is conformal to the outside scene, meaning that objects detected by the IR camera are the same size and aligned with objects outside the aircraft. Thus in poor visibility the pilot is able to view the IR camera image and is able to seamlessly and easily transition to the outside world as the aircraft gets closer to the runway.
The advantage of EVS is that safety in nearly all phases of flight are enhanced, especially during approach and landing in limited visibility. A pilot on a stabilized approach is able to recognize the runway environment (lights, runway markings, etc.) earlier in preparation for touchdown. Obstacles such as terrain, structures, and vehicles or other aircraft on the runway that might not otherwise be seen are clearly visible on the IR image.

APPENDIX B - REFERENCES

1. Eggert, Howes, Kuffner, Wilhelmsen, and Bernays Operational Evaluation of Runway Status Lights. Lincoln Laboratory Journal (2006)

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