OPERATIONAL CONCEPT & REQUIREMENTS FOR AIRPORT SURFACE SAFETY NETS

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Project: Airport Safety Nets for Pilots and Controllers

Issued: March 2010
## Title:

**OPERATIONAL CONCEPT AND REQUIREMENTS FOR AIRPORT SURFACE SAFETY NETS**

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<td>This report describes a EUROCONTROL operational concept for Airport Surface Safety Nets for Pilots and Controllers. It provides a description of potential operational concepts and aims to provide a starting point for the definition of a validation strategy for such concepts, using the European Operational Concept Validation Methodology (E-OCVM).</td>
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REFERENCES


4. Enhanced Traffic Situational Awareness on the Airport Surface with Indicators and Alerts (ATSA SURF 1A) Operational Services and Environment Description, Interim Draft Version 1.3, August 2008, SC 186 Working Group 1 Sub Group ATSA SURF 1A (not final draft), Contact pmoertl@mitre.org or jim.duke@alpha.org for more information


16. SESAR Definition Phase D4, ATM Deployment Sequence, SESAR Consortium, DLM-0706-001-02-00, January 2008


### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3D</td>
<td>three dimensional</td>
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<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance-Broadcast</td>
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<tr>
<td>AGL</td>
<td>Aerodrome Ground Lighting</td>
</tr>
<tr>
<td>ALCS</td>
<td>Aerodrome Lighting Control and Monitoring System</td>
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<tr>
<td>ASAS</td>
<td>Airborne Separation Assistance System</td>
</tr>
<tr>
<td>A-SMGCS</td>
<td>Advanced Surface Movement Guidance &amp; Control System</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATCO</td>
<td>Air Traffic Controller</td>
</tr>
<tr>
<td>ATIS</td>
<td>Automatic Terminal Information Service</td>
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<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATSA-SURF</td>
<td>Airborne Traffic Situational Awareness on the airport surface</td>
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<tr>
<td>CAA</td>
<td>Civil Aviation Authority</td>
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<tr>
<td>CAATS</td>
<td>Contract bAsed ATm System</td>
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<tr>
<td>CDTI</td>
<td>Cockpit Display of Traffic Information</td>
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<tr>
<td>D-ATIS</td>
<td>Digital Automatic Terminal Information Service</td>
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<tr>
<td>DCL</td>
<td>Departure Clearance</td>
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<tr>
<td>DMAN</td>
<td>Departure Manager</td>
</tr>
<tr>
<td>D-OTIS</td>
<td>Digital Operational Terminal Information Service</td>
</tr>
<tr>
<td>D-TAXI</td>
<td>Data-link TAXI</td>
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<tr>
<td>EASA</td>
<td>European Aviation Safety Agency</td>
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<td>EEC</td>
<td>EUROCONTROL Experimental Centre</td>
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<tr>
<td>EFB</td>
<td>Electronic Flight Bag</td>
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<td>EFMS</td>
<td>Experimental Flight Management System</td>
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<td>EFPS</td>
<td>Electronic Flight Progress Strips</td>
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<td>EFS</td>
<td>Electronic Flight Strips</td>
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<tr>
<td>EMMA 2</td>
<td>European airport Movement Management by A-SMGCS, Part 2</td>
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<tr>
<td>E-OCVM</td>
<td>European Operational Concept Validation Methodology</td>
</tr>
<tr>
<td>EUROCONTROL</td>
<td>European Organisation for Safety of Air Navigation</td>
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<tr>
<td>EVS</td>
<td>Enhanced Vision System</td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
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<tr>
<td>FIS</td>
<td>Flight Information Service</td>
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<td>FLIR</td>
<td>Forward Looking InfraRed</td>
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<td>GBAS</td>
<td>Ground Based Augmentation System</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>INS</td>
<td>Inertial Navigation System</td>
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<tr>
<td>IP</td>
<td>Implementation Package</td>
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<td>JAR</td>
<td>Joint Aviation Regulation</td>
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<td>KPA</td>
<td>Key Performance Area</td>
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<td>LoC</td>
<td>Lines of Changes</td>
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>MLAT</td>
<td>Multilateration systems</td>
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<td>NEAN</td>
<td>North European ADS-B Network</td>
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<td>NOTAM</td>
<td>Notification to Airmen</td>
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<td>NUP 2+</td>
<td>NEAN Update Programme Phase II+</td>
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<tr>
<td>OI</td>
<td>Operational Improvements</td>
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<td>PAPI</td>
<td>Precision Approach Path Indicator</td>
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<tr>
<td>R&amp;D</td>
<td>Research &amp; Development</td>
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<tr>
<td>R/T</td>
<td>Radio Telephony</td>
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<td>RTCA</td>
<td>Radio Technical Commission for Aeronautics</td>
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<td>RWY</td>
<td>Runway</td>
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<tr>
<td>SBAS</td>
<td>Satellite Based Augmentation System</td>
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<td>SESAR</td>
<td>Single European Sky ATM Research</td>
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<tr>
<td>SMR</td>
<td>Surface Movement Radar</td>
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<td>STCA</td>
<td>Short Term Conflict Alert</td>
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<td>SWIM</td>
<td>System Wide Information Management</td>
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<tr>
<td>TCAS</td>
<td>Traffic Alert &amp; Collision Avoidance System</td>
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<tr>
<td>TIS-B</td>
<td>Traffic Information Service-Broadcast</td>
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<tr>
<td>TWY</td>
<td>Taxiway</td>
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<tr>
<td>VOLMET</td>
<td>meteorological information for aircraft in flight</td>
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1. INTRODUCTION

1.1. GENERAL

This report provides a description of potential operational concepts for Airport Surface Safety Nets and aims to provide a starting point for the definition of a validation strategy for such concepts, using the European Operational Concept Validation Methodology (E-OCVM).

1.2. SCOPE

The focus of this report is on airport surface safety nets. Safety nets for airport surface movements are defined as ‘ground-based or airborne system automated applications that alert air traffic controllers, flight crews or airside vehicle drivers to potentially hazardous situations in an effective manner and with sufficient warning time for the situation to be resolved [13].

This report should be considered within the context of previous and ongoing initiatives in the area of airport surface safety nets. Particularly it should be considered within the previous work on A-SMGCS level 2 and the Airport Safety Net Roadmap which builds on operational requirements laid out by ICAO and is supported by an operational analysis of the key hazardous situations. The current report considers various airport safety net concepts, principally within the SESAR IP1 timeframe (although the exiting roadmap extends to period after 2013 as well).

It is important to highlight though that there has not been any formal pilot/flight crew input to the OpsCon and that this should be taken into consideration for further updates since the concept would benefit from review and feedback from pilots.

1.3. STRUCTURE OF THE DOCUMENT

The structure of the document is as follows:

- Section 2 describes the background to the issues with airport surface safety and the justification for the development of a concept for airport surface safety nets.
- Section 3 provides general benefits expected from airport safety nets introduction, problems and risks anticipated and general assumptions;
- Section 4 gives framework for discussion of operational concepts proposed;
- In Section 5, description of operational concepts is developed into more detail;
- Section 6 provides a summary and further discussion of the options in terms of advantages and disadvantages, and also identifies potential for integration of different concepts; and
- Section 7 describes existing safety nets, technological enablers required to support airport safety nets and maturity of technology options identified;
- Section 8 provides the set of operational scenarios to demonstrate the different options; and
- Section 9 lists all open issues.
2. BACKGROUND

2.1. OPERATIONAL ISSUES

The demand for travel from airports across Europe often means that traffic patterns at major airports tend to exhibit ‘peaks’ and ‘troughs’ over a 24 hour period. The ability of the airport to accommodate this varying demand will depend upon its capacity to accommodate the traffic. Indeed at some hub airports where demand remains high for extended periods of time the airport runs at or near capacity for the majority of its operational hours. Such situations mean that space available for surface traffic to move across the runways, taxiways and aprons is often limited. Providing a high level of safety under such circumstances is the highest priority and, based on experience over the past years, a considerable challenge.

When considering safety of operations on the airport surface, three distinct but closely related movement areas can be identified: runways, taxiways and aprons.

2.1.1. Runways

Safety issues associated with runway operations are well-known; they predominantly focus around addressing runway incursions. This is an area of known relative high risk (with a probability of collision higher than any other phases of flight). This area has therefore been a priority for improving safety in aviation for a long time [10].

A runway incursion, as defined by ICAO, is ‘Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft’ [11].

The distinction from the old definition is ‘incorrect presence’ which replaces ‘unauthorised or unplanned presence’ and consequently implies that incidents resulting from Air Traffic Control (ATC) error will now be captured as runway incursions. For example occasions when a flight crew correctly follows the issued clearance, but the clearance itself is erroneous and results in an ‘incorrect presence’ on the runway, will now be defined as runway incursions. This definition also encompasses situations in which an aircraft takes off (or lands) on the wrong runway.

Although there are many causal factors of runway incursions many can be traced back to human error. Poor communications, failure to follow procedures and ultimately a lack of situational awareness by actors involved will normally contribute to it [12].

A number of actions have been taken with the aim to reduce the number of runway incursions, such as: identification of best practices for safe runway operations; awareness campaigns focussing on the main contributing factors to the occurrence of runway incursions, e.g. phraseology; measures to improve situational awareness of the actors involved, e.g. clear signage for flight crew and vehicle drivers and a complete and correct traffic overview based on high quality surveillance for air traffic controllers (ATCOs). In addition to this, safety nets are being introduced to assist in detecting any runway incursions as soon as they occur, providing more time for the safe resolution of the problem.

2.1.2. Taxiways

A runway incursion has a relatively high safety criticality compared with other operations on the airport surface (the latter generally involve lower relative speeds and therefore do not present a high potential threat to human life). This fact meant that efforts to enhance airport surface safety
have largely been focused upon protecting the runway environment. Consequently relatively little attention was given to ATM systems that enhance the safety of airport taxiways.

The taxiway system of an airport is a complex environment – its layout is highly dependant on the local operational environment and with a high number of movements on the taxiways accidents between two aircraft, or between aircraft and vehicle do occur. The severity of such accidents may typically be less than that of accidents due to runway incursions, but the damage to property and operational efficiency can lead to high costs for airlines.

It is relatively easy for flight crews and vehicle drivers to become disorrientated on the surface of an airport, particularly if they are not familiar with the local procedures or taxiway layout. The lack of features on an airport surface, (which is generally a relatively barren environment) often serves to compound the problem, particularly in low visibility conditions. It is therefore vital that the flight crew can use surface lighting and signage to confirm their position on the airport surface when these visual aids are available.

A good level of communication between the flight crew and ATCO is vital to ensure that an instruction issued has been understood and is being followed. This is particularly important in very low visibility conditions when the flight crew may rely on the ATCO to report their position, (as presented to them by a surveillance feed) and visa versa.

The close proximity (but generally slow speeds) of traffic on the airport surface means that it can be very difficult to predict the immediate short term intent of mobiles. This is particularly the case with surface vehicles, which have a much higher agility then taxing aircraft (who, for example, may require a tow truck to reverse). As such, in relation to surface safety nets, it can be very difficult for an automated system to determine when a collision between mobiles on the taxiway is imminent without bombarding the operators with multiple false alters. The difficulty centres on what set of alerting criteria to use to set the threshold for triggering a short term conflict alarm. Use of safety nets on taxiway systems is for the moment not very common.

A number of the actions that were mentioned in relation to runways also apply to taxiways: the sometimes complex taxiway system can be very disorienting and measures such as clear and unambiguous phraseology and signage can help in reducing hazardous situations.

2.1.3. Aprons

Apron operations are distinct from those on the taxiway. The paths to be taken by surface mobiles are not defined by strips of hard standing – but instead by signage, surface markings and lighting systems. These references are used to orientate the mobiles as they move across the expanse of the apron. Typically a local set of procedures dictates what areas particular mobiles can operate in.

Operations can be even more space-constrained, then on taxiways with multiple aircraft and vehicles operating within a limited area, but typically at lower speeds than on taxiways. This environment typically has a much higher vehicle population serving it (e.g. including catering, refuelling, de-icing, push-back, and passenger transfer vehicles).

In addition, the aircraft are tightly packed together and their need to be pushed back from the gate before commencing on their routing across the airport surface must be coordinated with other surface traffic. This is needed to ensure that aircraft are not manoeuvred into a situation where they block one another’s path.

At many airports apron movements may be not be controlled by Air Traffic Control (ATC) at all as they are not considered as part of the manoeuvring area. In other instances, where a given
airline has exclusive use of a set of gates the apron control may be performed by the airline, using tools such as Departure Manager (DMAN) to indicate to ATC when an aircraft is likely to be ready for push back.

Taking all of this into consideration and the fact that it is very difficult to establish when the conflict occurs, it is necessary to highlight that inclusion of aprons in airport safety nets is very difficult and potentially impossible. However, aprons are kept for consideration in this project since there is a desire to cover as wide area as possible.

2.2. JUSTIFICATION FOR CHANGE

2.2.1. General

A number of initiatives have already been taken to improve airport surface safety, in particular in relation to the runway area. These initiatives address the full scope of people, procedures and equipment through awareness, best practices and information provision. Such initiatives focus largely on prevention of hazardous situations. The next step to take is to aim for providing warning to resolve the situation once a hazardous situation has occurred.

The initial steps on the development of safety nets have been taken within the context of A-SMGCS. A-SMGCS Implementation Levels 1 and 2 provide ATCOs two main services aiming at supplementing visual observation for traffic situational awareness (surveillance service), at raising awareness of potential hazardous situations and supporting ATC control actions (control service).

The Roadmap for Airport Surface Movement Safety Nets and hence this document build on top A-SMGCS Level 2 a series of surface movement safety nets aiming to:

- Increase the coverage of hazardous situations for surface movements (compared to A-SMGCS Level 2); and
- Provide direct alerts to flight crews and vehicle drivers (when relevant).

Therefore, there is a need to address these issues and some of the shortcomings that still exist. This means moving towards a safety net function that covers the full airport movement area and improves warnings to enable a safe resolution of the situation. To provide a justification for this, the causes of hazardous situations on the airport surface and the types of situations need to be understood. In addition, it is necessary to assess the effect that alerts may have on the actors involved and some further aspects of the operational environment that may affect the successful application of safety nets.

2.2.2. Understanding the causes

To define an operational concept for airport surface safety nets, some understanding of the causes leading to hazardous situations is necessary. In principle, the cause of a hazardous situation should not affect the way any safety net performs, but understanding the causes may improve the success rate of a safety net (in terms of enabling a safe resolution). With some level of understanding of the cause, typical actions leading to a specific situation can be more easily recognised and likelihood of successful resolution can be increased through optimised alerting. To clarify this further, the following example should be considered.
A hazardous situation is caused by a disoriented flight crew that enters an active runway without clearance. Provision of an alert to the flight crew to make them aware of this can be considered as a concept.

- If the alert can be presented to the flight crew in such a way that it provides them with sufficient information to safely resolve the situation, this may be a good concept.
- If, on the other hand, an alert is likely to only add to the confusion of the flight crew, an alternative concept is preferable.

A full analysis of all possible causes would be too detailed for the purpose of the current report; therefore the focus is on the main high level issues which are considered relevant in relation to safety nets.

The ‘Preventing runway incursions’ portal of the EUROCONTROL Runway Safety project [14] names three main issues that lead to runway incursions: loss of situational awareness, breakdown of communications and errors. These main categories are assumed to be applicable also outside the runway area, on the taxiways and aprons.

**Loss of situational awareness**

A modern airport can be a large and complex environment in which flight crew can get lost whilst trying to navigate their way from parking stand to runway or vice versa. Similarly, during periods of high traffic load, ATCOs are at risk of losing the overview of which aircraft is going where. This problem can be exacerbated if the airport has grown over the years and the available infrastructure was expanded accordingly, leading to a sub-optimal overall infrastructure. In addition, it is very common that ATCOs view of the manoeuvring area becomes obscured as a result of ad hoc additions to airport facilities blocking what was previously a clear view.

Loss of situational awareness does not necessarily relate only to location and identification of mobiles, confusion about clearance status can also occur. This is particularly relevant to ATCOs who have to keep track of status of multiple targets at the same time.

Loss of situational awareness by a flight crew can lead to aircraft inadvertently moving onto the wrong taxiway or a runway, or into a restricted area. If an ATCO loses overview, there is a risk of aircraft being provided with incorrect instructions.

**Breakdown of communications**

High loading of radio telephony (R/T) means some communications can be lost, missed or misunderstood. This can lead to unexpected behaviour of aircraft or vehicle, because flight crew or vehicle driver and ATCO have a different understanding of the status of the mobile (in terms of e.g. route or clearance).

**Errors**

Errors are situations in which a ATCO, flight crew or vehicle driver accidentally performs an incorrect action, such as crossing a stop bar, issuing a wrong clearance or turning onto a wrong taxiway. Errors are often closely related to the first two categories: loss of situational awareness and breakdown of communications. For example, a clearance being provided by an ATCO to the wrong aircraft, or a flight crew turning into a wrong taxiway could also be attributed to a (momentary) loss of situational awareness.
The first course of action in reducing the chance of occurrence of the three main categories described here is through prevention. For example, the main issue in addressing loss of situational awareness is through provision of information to improve situational awareness in general, and improve the ability of all actors to maintain good situational awareness. When a safety net function is then considered as a next step, this rationale should be extended to the safety net, if it is to address the hazardous situation successfully: any alert or warning has to be presented in such a way that the details of the situation (in particular mobiles involved and their location and direction of movement) are presented in a clear and unambiguous way.

Applying the same rationale to breakdown of communications, there are areas that can be addressed to prevent these kinds of occurrences, such as standardised phraseology. In terms of safety nets, the situation is also similar to loss of situational awareness, as some part of the operation has been missed or misunderstood, meaning it is important to provide all the correct information as part of the safety net function output, to eradicate the information that was ‘corrupted’ by the breakdown of communications.

2.2.3. Understanding the types of conflicts and alerts

The ICAO ‘European Manual on Advanced Surface Movement Guidance and Control Systems (A-SMGCS)’ indicates that the following short term alerts “should be provided within an adequate time to enable the appropriate immediate action:

- Short term conflict alert, whereby an A-SMGCS triggers an alert when predicted separation will be below preset/predefined minima (note: there are no separation minima on taxiways);
- Area penetration alert, whereby an A-SMGCS triggers an alert when a movement is detected as likely to enter a critical or restricted area;
- Deviation alert, whereby an A-SMGCS triggers an alert when computed deviation will be more than the preset/predefined maximum deviation;
- Runway incursion alert, whereby an A-SMGCS triggers an alert when a movement is detected as likely to enter an active runway (runway strip); and
- Taxiway (or an inactive runway being used as a taxiway) or apron incursion alert, whereby an A-SMGCS triggers an alert when a movement is detected as likely to enter a taxiway or apron in use which does not belong to his assigned route.”

These five alerts were used as the starting point for the roadmap [13] and will also be used here. For the purpose of the study, the generic definitions used by ICAO will be applied through the following, more pragmatic interpretations:

- A short term conflict alert, similar to an airborne STCA, relates to conflicts due to a predicted or actual loss of separation between two aircraft or an aircraft and a vehicle. Examples are two aircraft approaching the same taxiway junction from different directions, or a fast taxiing aircraft following a slow taxiing aircraft on the same taxiway.
- An area penetration alert aims to protect any areas of the airport that are safety critical or, either temporarily or permanently, restricted for aircraft and/or vehicles, and the alert will be triggered if a mobile enters or is expected to enter such an area.
- A deviation alert, where a mobile deviates from a given routing across a runway, taxiway or apron is a more complex situation. This is because the safety net system is required to have some level of awareness of the clearance status and cleared route of the aircraft or vehicle. Examples of situations where such an alert would be generated include instances when aircraft move onto a taxiway that is not part of the cleared route, a pushback or taxiing
manoeuvre is initiated without a clearance or when taxing continues beyond the end of the cleared route.

- A runway incursion alert warns actor(s) about either a predicted or in-progress runway incursion (as defined by ICAO). Finding the key to engineering and/or implementing such a system so that it provides timely and useful alerts is difficult. This is typically because it is hard to establish whether a mobile moving onto the runway surface is a ‘correct’ action (i.e. one that was planned by the ATM system) or not.

### 2.2.4. Understanding the impact of providing alerts

One of the challenges in providing any type of alert in any environment is defining the correct alerting conditions. To identify a situation as hazardous and requiring an alert to be raised to an actor, a safety net function needs a defined set of parameters against which it can evaluate the situation. If the evaluation, based on the parameters, considers that a constraint has been breached and a hazardous situation is occurring, an alert will be generated.

The difficulty in this is setting the alerting parameters in such a way that an acceptable balance is achieved between:

- Setting the parameters tight enough, so that whenever an alert is generated the situation really is considered in line with expectations of the alert level, and there is sufficient time available to resolve the situation without leading to an accident;
- Not setting the parameters too tight so that whenever a hazardous situation occurs and an alert is generated; otherwise the ATCOs will become desensitised to the alerts – viewing them as an impediment to either capacity or safety and a benefit to neither.

Within the context of these two competing nets it should be remembered that overall the safety net should allow the ATCOs to maintain capacity with the same or increased level of safety.

If alerting parameters are not tight enough, a safety net function may generate many false or nuisance alerts: alerts in relation to situations that are not considered as requiring an alert according to the actors involved. Such alerts will reduce acceptance of the safety net function.

All of the above should be seen in relation to the purpose of the alert or alert level (if the alert has different levels, e.g. amber and red): is it aimed at raising awareness and drawing attention of the relevant actors to a situation which may develop into a hazardous situation, or is it aimed at identifying actual hazardous situations that require immediate action?

### 2.2.5. Understanding the influence of the operational environment

The concept for safety nets on the airport surface is quite different from the safety nets in existence (and under development) for airborne aircraft. The most obvious difference is the distance between aircraft (and, on the ground, vehicles). In the air, significant radar separation is applied whereas on the ground aircraft movements often take place in close proximity to each other. This leads to a key difference in the timings of the alert, the time to closest point of approach, and the timeliness of action for the flight crew or ATCO.

Other clear differences can be found in the relevant constraints: flying aircraft have a limited manoeuvrability in terms of sudden changes in speed or direction of flight (i.e. aircraft are flying on a pre-defined path and profile), making their future position relatively predictable, yet have a large degree of freedom in terms of taking evasive action in a conflict situation.
On the ground, in relative terms, movements are much more flexible, direction of movement can be changed quickly and speed can vary and includes the potential to come to a complete standstill. At the same time, the movement of aircraft is normally limited to the system of available taxiways and runways.

Aircraft should be following ATC instruction while moving on the ground so their movements should be easy to predict. However, the flexibility in ground movements mentioned above makes these movements very difficult to predict without information on intent: if an aircraft is moving towards a taxiway junction, it is difficult to tell in advance whether the aircraft will turn left or right; if an aircraft is moving towards a stop bar, it is difficult to predict in advance whether the aircraft will stop or ignore the stop bar and continue taxiing.

This lack of predictability, in combination with the close proximity of movements means that any deviation of a route can quickly develop into a hazardous situation, and makes airport surface safety nets a difficult issue to address.

Visibility

Safety nets should function under different visibility conditions. The various conditions can affect a number of different aspects of the safety nets:

- Safety margins and alerting rules. These are likely to differ between visibility conditions, as larger margins are applied in low visibility.
- Ability to act. During periods of low visibility, the ability for both ATCOs and flight crews to visually observe the traffic situation changes. ATCOs become highly dependent on surveillance information, but at least they will continue to have a global overview. For flight crews and vehicle drivers, the ability to observe the surroundings of the aircraft, including any nearby traffic reduces with reducing visibility, potentially limiting the ability to take the proper corrective action in case of an alert being presented to them.
- Visibility of safety net equipment. If alerts are presented to flight crews through equipment, most probably lighting, on the airfield, the ability to see this equipment may become an issue in conditions of very poor visibility.

Layout

Airport layout will have an influence on the most likely types of conflicts that may occur at the airport, and therefore on the situations that a safety net should focus on. Examples are taxiway/runway crossings, crossing runways, complex taxiway junctions, presence of restricted areas. Therefore, alerting algorithms (or, at a higher level, alerting methodologies) must be capable of being adapted to the local environment into which the surface safety net is implemented.

Available systems and procedures (ground and air)

The systems available to flight crews and ATCOs and the procedures, roles and responsibilities applicable at an airport can have a significant impact on the successful implementation of an airport safety net. Examples are the quality and coverage area of the surveillance system and the different control positions responsible for different areas of the airfield. However, the concepts under discussion in this report are considered at a generic level and detailed systems and procedures should only be considered when moving towards applying safety nets within a specific environment.
2.2.6. Summary

In the introduction of Section 2.2, expansion of the A-SMGCS level 2 concept was mentioned in two areas: in terms of the actual area covered, expanding from runway only to the full movement area, and in terms of improving the alerts that are provided, to enable increased success rates in resolving hazardous situations.

Covering the movement area

Initial focus on the runway areas is justified by the number of incidents reported in combination with the potential disastrous consequences of a runway accident. With ever growing traffic levels and pressure on efficient operations during all phases of flight from gate to gate, including before take off and after landing, increased focus is required on maintaining safety level on the whole airport surface. Therefore, there is now a need to expand the focus of safety nets to the taxiway and apron areas and introduce an integrated airport surface safety net function.

Improved alerting

Developments in relation to A-SMGCS level 2 have shown that, although a useful addition to the system, the relevant safety net function is not always sufficient. Further concepts need to be explored to improve overall alerting performance (to be interpreted here as successful resolution of a hazardous situation being enabled by an alert). One obvious approach is earlier alerting, however, from Section 2.2.4 it is clear that earlier alerting will not always be possible without negative side effects. Therefore, a second approach is creating a more direct ‘communication’ between safety net function and flight crews.
3. GENERAL BENEFITS, PROBLEMS, AND ASSUMPTIONS

The following sections provide general view of benefits sought by introduction of airport safety nets [13], while more specific benefits of each operational concept proposed will be given in Section 5. In addition this section addresses issues of false alerts and general issues related to the way in which alerts are given to ATCOs and mobiles. The section concludes with a general list of assumptions taken into account in the development of the operational concepts.

3.1. OPERATIONAL BENEFITS

3.1.1. General perspective

The prevention of the key hazardous situations aims at mitigating the risk of conflicts and collisions between aircraft or between aircraft and vehicles. In addition, the use of safety nets may reduce potential damage caused to aircraft or the risk of injury to aircraft crews, passengers and ground personnel (e.g. in case of severe breaking actions during taxi or due to the effect of jet blast during surface movements). Furthermore, the detection of potentially hazardous situations contributes to the efficiency of surface movements and mitigates the risk of operational disruptions.

3.1.2. ATCO perspective

Compared to A-SMGCS Level 2, the main operational advantage sought by ATCOs with new airport surface movement safety nets is increased time available to identify what actions need to be taken and instruct the concerned flight crew or vehicle driver. The success of any intervention is improved where the controller is made aware of the risk earlier.

3.1.3. Flight crew perspective

The support from automation to flight crews for airport surface movement is aimed at increasing their situational awareness and preventing dramatic consequences of undetected hazards or operational errors. However, flight crews shall be kept as much as possible out of the loop of the ATC process of determining corrective actions (although not emergency manoeuvres). This is important to avoid their critique of the ATCO options or could lead to missed messages due to heavy workload and a constant requirement for head-down processing of information.

The primary source of information during surface movements is visual observation. However, automated support may offer benefits for navigation on complex airport layouts, in degraded visibility conditions (night, rain, low visibility) or in case of high crew workload.

3.2. PROBLEMS AND RISKS

• False alerts. The EUROCONTROL A-SMGCS specification for Level 2 recommends a maximum false alert level of 3 per week (at level ALARM) for runway conflicts. However, a different level of false alerts may need to be assessed for hazardous situations on taxiways due to the increased number of aircraft manoeuvring simultaneously on such area (compared to runways) and the fact that no separation distance between aircraft is currently defined. As for ATCOs, the rate of false alerts is a major issue for the acceptance of safety nets by flight crews. Potentially higher integrity levels will be required for on-board applications compared to the A-SMGCS Level 2 alerting service (ground
application). This is because pilots do not have the same level of situation awareness as controllers.

- **Segregation of alerts.** The possibility of ‘segregating’ ground and on-board alerting functions with a different look-ahead time is not deemed feasible (there is no minimum separation distance defined for surface movements and visual observation remains primary source of information). This is a key difference compared to safety nets for the airborne phase (STCA and TCAS).

- **On-board safety nets.** During the development of the proposed on-board safety nets, the issue of having non-ambiguous and non-contradictory interpretation of alerts provided on ATCO side and mobile side needs to be further investigated. This includes:
  
  o Detection and alerting functions should be validated so that there are no cases where contradictory information provided to ATCOs, flight crews or vehicle drivers exist (e.g. hazard detected on one side and no hazard detected on the other side).
  
  o The integrity of surveillance information available to aircraft from multiple sources should be demonstrated (from cooperative or non-cooperative aircraft, vehicles, or using for instance the traffic situation picture provided to ATCOs (A-SMGCS Level 1 system).

### 3.3. ASSUMPTIONS

Two main assumptions related to roles and responsibilities or the availability of potential operational services within 2007-2013 timeframe have been made:

- No changes to the current respective roles and responsibilities of ATC controllers, flight crews and vehicle drivers for airport operations are anticipated in the 2007-2013 timeframe; and

- The provision of “electronic vision” to flight crews (or vehicle drivers) is covered by the Roadmap but not to the point where the “see and avoid” principle that prevails in Visibility Conditions 1 and 2 is also applicable in Visibility Conditions 3 (when flight crews cannot avoid each other using visual information).

The assumption with respect to the airport technology is that:

- Development of airport safety nets is based on A-SMGCS level 2.

The assumption with respect to airport environment is that:

- The proposed airport safety nets provide their role under all visibility conditions.

The assumption with respect to safety nets functionally is that:

- The detection and alerting processes for the key hazardous situations cover the alerting of ATCOs (in all cases), flight crews (for suitably equipped aircraft) and drivers (for suitably equipped vehicles) about a potential hazard (i.e. situation awareness) BUT NOT the provision of resolution advisories.
• The role of on-board surface movement alerting function(s) is assumed to increase the situational awareness of flight crews and vehicle drivers, provided that the SAME situational awareness is presented to ATCOs.

• The recovery of the hazardous situations is left to the ATCO, provided that sufficient time is available to identify the required action(s) and to instruct the flight crew/vehicle driver. Option of recovery given to flight crew should be considered only for emergency actions. However, it is important to note that flight crew will take whatever action they deem necessary for the safe operation of the aircraft and that this assumption does not override their responsibilities.
4. FRAMEWORK FOR DISCUSSION OF OPERATIONAL CONCEPTS

This section presents the framework for discussion of operational concepts starting with the high level description of operational scenarios for airport surface safety nets. This is followed by description of actors involved, system functionality, and system architecture considerations.

4.1. CATEGORISATION

This section describes at a high level the general operational circumstances where it is expected that the airport surface safety nets will play a role in mitigating potentially hazardous situations.

Identification of operational concepts for surface safety nets can be structured around their definition set out in Section 1. Here they were defined as systems that provide an "automated alert to either the flight crew, the air traffic control officer (ATCO), or the vehicle driver". It therefore naturally follows that they should be considered in terms of which actors are alerted by their use; i.e. whether the safety net is aimed at:

- Flight crew and vehicle drivers (mobiles),
- ATCOs, and
- Both mobiles and ATCOs.

This same definition goes onto describe the system functionality of a safety net as being one that provides an automated alert to an actor of "potentially hazardous situations". It is necessary to distinguish between different types (or 'categories') of "potentially hazardous situations" for which an automated alert could be provided by a safety net system in order to define a framework for their discussion. This has been done below by defining three separate categories of situations that are designed to be:

- Sufficiently broad so that between them they cover all major types of potentially hazardous situations;
- Allow easy categorisation of particular operational scenarios; and
- Provide enough granularity for a strong concept of how they would operate to be defined.

The three main categories are:

**Category 1: Non-conformance to ATC instructions/procedures**

- In general, the causal factors that create this category of "potentially hazardous situation" are largely expected to be due to mobile operator error.

- This situation is caused when traffic deviates from its assigned 3D-trajectory (the two dimensions on airport surface and the associated time dimension); i.e. does not adhere to the apron/taxiway/runway routing assigned to it. This category includes situations such as:
  - Non-compliance to the ATC clearances by flight crew and drivers in the proximity of active runways, e.g. aircraft/vehicle do not stop at the runway holding point;
  - Where a communication misunderstanding occurs between what is meant by the instructions of the ATCO and what is interpreted by the mobile operator (e.g. as a
result of communication break-down, through say callsign/conditional clearances confusion, incorrect/missed read-backs, poor phraseology, lack of R/T).

• This category also covers deviations from standards operating procedures and practices by mobiles, such as aircraft taxiing with extreme taxi speed that can indicate for example intention to take-off from the taxiway.

Category 2: Conflicting ATC clearances

• The causal factors generating this category of situation will always reside with the ATCOs.

• This type of situation is generated when ATC provides mobiles with clearances that, if followed, would bring them into conflict with other mobiles. This category includes situations when:

  o Conflicting ATC clearances which could result in a runway incursion, e.g. an aircraft is cleared to take off and another mobile is given a crossing clearance in front of the aircraft on the same runway;

  o Aircraft follow the clearances of ATC to find themselves facing each other and unable to proceed without assistance from tugs. For example an aircraft may be instructed to push back from a gate and in so doing proceeds to blocks a taxiway/apron routing until the ATCO gives further instructions.

Category 3: Infringement of restricted/closed areas

• This category refers to situations when mobiles, whilst complying with the clearances issued by ATC, are routed through restricted or closed areas (which can be taxiways, runways or aprons). At the same time, these can refer to situations where mobiles penetrate restricted or closed areas without authorisation from ATC. In these situations mobiles are failing to comply with airport signage or published procedures and this is likely to be as much of a cause of infringement as not following ATC instruction.

• Therefore potentially hazardous situations in this category can be assigned both to mobile or ATCO error. However, in general “potentially hazardous situations” in this category are likely to be caused by ATCO error – i.e. aircraft complying with clearances that guide aircraft to an inaccessible area or blocked route. This category refers to following situations:

  o It requires a routing to be agreed between ATCO and flight crew and for the flight crew not to deviate from it. Includes instances when the route passes through a restricted movement area of the airport surface or another mobile (i.e. such that it is blocked). As such this category includes those safety nets that provide proximity warnings to surrounding traffic.

The above three categories for airport safety nets are ‘event driven”; the classification of a scenario as belonging to one or the other depends upon whether the routing taken by the mobile at any given moment in time is that which the ATM system has planned for it. A Category 2 situation will be created the instant that a conflicting ATC clearance is issued by the ATCO and will persist even if a subsequent Category 1 or 3 situations is triggered. In situations where both Category 1 and 3 events have occurred, the scenario classification depends upon the order of events. A situation where a flight crew first deviates from a cleared route and then finds that this route blocked would activate both Category 1 and Category 3 (as the safety net is generated at the instant the aircraft moves ‘off route’ and persists even when the Category 3 situation is generated).
The contrary situation where flight crew finds his route blocked (i.e. a Category 1 situation) but then proceeds to deviate from his cleared route is not a credible operational scenario. This is because a flight crews operational procedures do not allow deliberate route deviation (e.g. taxing) without first securing a proper clearance from the ATCO. Therefore, for example, if the taxiway is found blocked the flight crew should call for instructions. The classification applied to scenarios is illustrated below in ‘event trees’.

**Figure 1: Event trees for operational concept categorisation**

The nature of the alert (including any resolution advisories provided) will depend on the operational service and environment of the actor to which it is provided. In other words alert can be provided to either the tower ATCO, the Mobile (either a flight crew or vehicle driver) or to both parties. The table below uses this discussion to isolate nine independent operational concepts, each of which will be investigated in turn.
## Table 1: Categories of operational concept identified

<table>
<thead>
<tr>
<th>Environment</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile</td>
<td>Mobile 1*</td>
<td>Mobile 2*</td>
<td>Mobile 3*</td>
</tr>
<tr>
<td>Tower</td>
<td>ATCO 1</td>
<td>ATCO 2</td>
<td>ATCO 3</td>
</tr>
<tr>
<td>Both</td>
<td>Both 1</td>
<td>Both 2</td>
<td>Both 3</td>
</tr>
</tbody>
</table>

* = surface mobiles will be considered alongside aircraft, with notes added as appropriate to account for the differing handling, size characteristics, between them.

### 4.2. ACTORS

Given that the main concept options are defined around the actors involved, it is useful to consider these actors in a bit more detail:

- ATCOs are responsible for ensuring the safe and expeditious flow of traffic on the airport surface. As ATCOs with different roles and even from different organisations can be responsible for different areas of the airport, and communications between these ATCOs can be an important factor in both cause and resolution of a conflict, the ATCO role is broken down here into three further categories:
  - Runway ATCOs, (known as the “Tower” service), who are responsible for all movements on the runway, i.e. landings and take-offs but also crossing or taxiing as required. Typically, runway ATCOs will also be responsible for aircraft queuing for departure at one or more runway entry points. In some cases, mobiles will be allowed onto a runway without being on the runway ATCO frequency, but in such cases these movements are expected to be clearly coordinated with the runway ATCO.
  - Taxiway ATCOs, (known as the Ground ATCOs), responsible for all movements on the taxiway system.
  - (Optionally) Apron managers, responsible for movements on the aprons.
  - More than one ATCO of each role can be active on an airport at one time, particularly where multiple runways exist. Similarly, different roles can be combined and performed by a single person.

- Flight crews, responsible for safely navigating the aircraft across the airport surface according to established procedures and the instructions and clearances provided by air traffic control.

- Vehicle drivers, who similar to flight crews, are responsible for safely navigating their vehicles across the airport surface according to established procedures and the instructions and clearances provided by ATC.
4.3. SYSTEM FUNCTIONALITY

4.3.1. Non-conformance to ATC instructions and procedures

Most surface safety nets today work without knowing intent in any way. They rely on short term vector extrapolation and boundary infringement zones. However in support of the operational concept identified in Table 2 the surface safety net will require the following information:

- **The cleared routing of the mobile(s) concerned:** Information about this dynamic will mainly be contained within the clearances issued by ATC to the mobiles on the airport surface. As such it needs to be constantly updated in real time to reflect what the current “cleared routing” for the mobile is. Information needed will include:
  - the start point (e.g. runway exit);
  - routing (e.g. waypoints and taxiways to be followed);
  - the hold short of points (holdbars) and stop bars;
  - the final destination; and
  - actions to take (e.g. line-up and hold, commence take-off roll, stop at gate, park, seek clearance from runway ATCO).

- **The current location of the mobile(s) concerned:** This will provide the system with a picture of what movements are currently taking place on the airport surface in relation to those targets that present a risk to the system.

The cleared routing for the mobiles can then be compared with their current locations/intentions to determine whether or not a mobile is deviating from its cleared route (or if it intends to do so).

4.3.2. Conflicting ATC clearances

This system safety net will require knowledge of what clearances have been issued by ATC and what the current locations of the mobiles on the airport surface currently are. This will enable the system to determine what routing has been assigned to each and every mobile to determine what conflicts, if any, have been produced by a given set of ATC clearances.

4.3.3. Infringement of restricted/closed areas

For this surface safety net to function the following information may need to be provided to the system:

- **The cleared routing of the mobile(s) concerned** (as above);
- **The current location of surface mobiles concerned** (as above);
- **The location of restricted/closed areas on the airport surface:** including areas covered by restrictions and the periods when they are in force (e.g. boundary infringement zones).
4.4. SYSTEM ARCHITECTURE CONSIDERATIONS

4.4.1. Sources of input and location of safety net function

This subject is a combination of two factors that should be considered interdependently to one another:

- the ‘location’ of the technical safety net function itself, i.e. whether the safety net function is part of the ground-based (ATC) system or of the onboard system; and
- the source of information for the safety net function, i.e. how the traffic information was gathered.

The main characteristics of the surface safety net are therefore shown in the following figure (including the location of the safety net, i.e. the output).

![Figure 2: Simplified architecture](image)

For all three blocks presented in Figure 2, an ‘ATC side’ and a ‘mobile’ side’ option is available:

- Required information elements (these can include traffic information and possibly ATCO clearances etc.) as input to the safety net function. These can be gathered from the ATC system as output of the surveillance function (e.g. via Traffic-Information-Service-Broadcast (TIS-B) functionality), or directly from the mobiles on the airport surface through e.g. Automatic Dependent Surveillance-Broadcast (ADS-B).
- The safety net function can be part of the ATC system or of the onboard system of aircraft and/or vehicles.
- The output of the safety net function, as already indicated in Section 4.1, can be presented to ATCOs or to flight crews/vehicle drivers.

Table 2 summarises the possible outputs and examples of technological enablers.

<table>
<thead>
<tr>
<th>Input</th>
<th>Function</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower (ATC side)</td>
<td>surveillance function</td>
<td>part of the ground-based ATC system</td>
</tr>
<tr>
<td>Mobile (Aircraft/Vehicle side)</td>
<td>ADS-B (via TIS-B functionality)</td>
<td>onboard system of aircraft and vehicles</td>
</tr>
</tbody>
</table>

Table 2: Summary of possible options

However, not all combinations of input, function and output (i.e. having part of the chain on one ‘side’ and part on another ‘side’) are considered realistic. As illustration, an obvious example of an architecture that is not considered realistic is when input is received through the ATC surveillance system and output is presented to the ATCO, but the safety net function...
is an onboard function. This would lead to easily avoidable equipage requirements, as well as unnecessary additional data communications.

Therefore, with input from and output to the ATC side, only a safety net as part of the ATC function is considered a realistic option.

Looking at the different combinations of source of input data and presentation of output, the following options are considered credible (with the relevant rationale):

- The situation where input is provided by the surveillance function of the ATC system and output is to the ATCO only was discussed in the example above. With this combination of input and output, only safety net as part of ground system are considered to be realistic.

- The same argument can be applied for gathering input on traffic situation through onboard systems and providing output to flight crew. In this instance only safety net as part of onboard system is considered realistic.

- If the input on traffic information is received through onboard systems and the output is presented to the ATCO, the safety net function can in principle be part of the onboard system (in which case only information on the alert itself is transmitted to the ATC system) or of the ATC system (in which case the aircraft transmits relevant data to the safety net function, which then presents an alert to the ATCO if necessary). However, in the latter case, the data ‘transmitted’ by the onboard system should be related to information such as aircraft status, position, and such data is unlikely to be used directly by the ATC safety net function. It is more likely that such data will be received and processed by the ATC surveillance function and then presented as input to the ATC safety net function as part of the surveillance data input. This makes this option identical to the option discussed above under the first bullet (safety net using surveillance function input and presenting output to ATCO) and therefore only a safety net as part of the onboard system is considered to be realistic for this combination of input and output.

- If traffic information is received through the ATC system and output is presented to flight crew, the safety net function can be part of the onboard system or the ATC system. However, flight crew alert in this case may be delayed. Both options are considered realistic.

This leads to five options which are considered realistic. These options will be considered within the context of the concepts described in Section 4.

Additional options could be envisaged if the safety net alert if delivered to both the ATCO and flight crew/vehicle driver (already suggested in Section 4.1 when ‘aimed at both flight crews/vehicle drivers and ATCOs’ was identified as one of the main concepts). Advantages and disadvantages of these options will also be discussed in Section 5 and Section 6.

As a final comment, it should be noted that the options of Section 4.1 are identified with the intention to distinguish their operational characteristics and impact. The issues under discussion here should be seen in this context: at this stage the aim is not to provide significant detail on the technology and equipment required for the inputs and outputs.

4.4.2. Types of outputs

In terms of outputs, a number of alternatives may be considered:

- Different levels of alert, depending on severity (e.g. “caution” - yellow and “warning” – red, as adopted in NUP II+);
• Identification of type of alert (e.g. runway incursion, deviation);
• Identification of mobiles involved; and
• Provision of resolution advisory, traffic advisory (similar to TCAS), or action to be taken.

It should also be noted that ‘output to flight crew/vehicle driver’ does not necessarily mean output via an onboard system, e.g. airfield lighting gives a direct indication to a flight crew without relying on equipage.

The levels of alert raised to the ATCO, driver or flight crew by the safety net will depend on the mobile’s position on the movement area and the routing/intent of the surrounding mobiles. It is envisaged that different alerts for different situations will be presented to the flight crew/driver or ATCO following:

• Deviation from assigned route or area penetration;
• Runway monitoring and conflict alert; and
• Runway incursion.

These in turn can be mapped to the ICAO defined alerting system. The ICAO ‘European Manual on Advanced Surface Movement Guidance and Control Systems (A-SMGCS)’ short term alerts were provided in section 2.2.3.

Alerts are triggered dependent on scenario and are sensitive to various factors that include time to the conflict, ownship operation, movement and position of the conflict aircraft, available flight crew responses, as well as the level of uncertainty. It is assumed that alerts are presented sequentially if more than one alert is provided in a given scenario. The principles for the presentation of alerts including indication and altering principles - including when and how these would be triggered are set out in section 2.1 of [4].
5. DESCRIPTION OF OPERATIONAL CONCEPTS

5.1. GENERAL

Based on the framework developed in Chapter 3, this section develops detailed descriptions of the different types of operational concept identified in section 4.1 (see Table 1).

<table>
<thead>
<tr>
<th>Operational Environment</th>
<th>Cockpit</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cabin</td>
</tr>
<tr>
<td>Mobile</td>
<td></td>
</tr>
<tr>
<td>Operational Concept</td>
<td>Mobile 1</td>
</tr>
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<td></td>
<td>Mobile 2</td>
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<td></td>
<td>Mobile 3</td>
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<tr>
<td>Tower</td>
<td>Tower</td>
</tr>
<tr>
<td>Operational Concept</td>
<td>ATCO 1</td>
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<td>ATCO 2</td>
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Table 3: Categories of Operational Concepts to be considered

In describing the operational concept this section provides a high level overview of the operational service and environment of the actors involved and examines the various types of information available to them.

The functionality of the system supporting the concept will initially be discussed independent of the technology applied. However the nature of the data provided as inputs into the system (e.g. its quality, completeness, level of detail) is highly dependant on the types of underpinning technology used to provide it. Therefore, the operational concept description is extended to include a breakdown of these technological enablers.

*NB: in the following discussion and accompanying descriptions all actors are referred to as “him” for ease of readability.*
5.2. MOBILE BASED

Figure 3: The operational environment of mobiles - the flight crew’s cockpit and driver’s cab

5.2.1. Operational context

The operational service provided by the flight crew or driver of a vehicle is the safe navigation of his craft around the airport surface. The provision of safety net alerts are considered to be the operational application under consideration.

Importantly, mobile based surface safety nets are generally restricted in their scope in only providing alerts relating to the safety of ownship – not the system as a whole. Flight crew and drivers when moving around the airport surface act on the instructions from the apron, ground or runway ATCO as appropriate. This includes complying with any clearances or advisories issued to them by the ATCOs (see section 1.3 of [4]).

5.2.2. Operational environment

The cockpit/cab

The flight crew gains situational awareness from the operational environment; i.e. the instrumentation panels in the cockpit and what visual clues he can glean from a visual scan of the airport surface. The crew principally seek information on:

- Location, both absolute and in relation to the surrounding traffic; and
- What routing he needs to be followed (generally taken from signage on the airport surface except in very low visibility conditions).

Visual: The prevailing meteorological conditions will dictate what information can be gleaned by a visual check from flight crews or drivers when moving around the airport surface. In high visibility conditions they will be able to orientate themselves relative to other mobiles and landmarks on the airport surface. At night, surface lighting and illuminated signs are vital in this process. In some situations, situational awareness may be impaired by low visibility, such that the likelihood of disorientation or loss of awareness of other traffic increases. In these conditions drivers and flight crews become more reliant on those objects on the airport surface that they can still see – such taxiway markings, signage and lighting systems – to provide a visual confirmation of their location. In very low visibility conditions, when even
these surface based visual cues can become obscured, the flight crew or driver will become more dependent on in-cockpit or in-cab systems to determine his position, for example heads-up displays.

**Audio:** Communications are received by mobile operators from the ATCOs controlling the movement of traffic around the airport surface.

There will typically be more than one frequency for ATC communications. Most airports will have at least two separate frequencies, one for ground and the other for the tower (or ‘runway’) ATCO. In particularly complex operational environments areas of ATCO responsibility will be further divided (with responsibility for the surface movements on the various taxiways delegated between ATCOs). It is therefore likely that the flight crew will not be able to gain a full traffic picture by listening to a single frequency (although a reasonable situational awareness of the traffic operating in his immediate vicinity may be gleaned).

Audio communications are usually in the form of requests for and issuance of clearances and directions to various holding points on the airport surface (e.g. “Taxi via Alpha and Bravo to holding point RWY 27”). Further “hand-over” instructions – i.e. for the mobiles to contact different radio frequencies are also provided to the traffic as the mobiles move from one area of responsibility to another. In low visibility conditions the flight crew may verbally report his position to the ATCO based upon information he gleans from ground signage and lighting systems. Information about the location of restricted areas, such as those of active runways and construction sites that the flight crew or driver may encounter en-route are generally communicated as published traffic advisories rather than verbally.

**In-cockpit guidance - Heads down displays:** These can include items such as airport surface charts (in either paper-based or electronic forms) and moving maps. Electronic guidance systems in the aircraft cockpit are generally provided through Electronic Flight Bags (EFBs) whereas GPS-based navigation hand-held devices are used in the vehicles’ cabs. In both cases, the display of the ownship position (via GPS) on the airport surface (via an electronic database) is the fundamental component of the guidance.

More advanced systems may also display the position of surrounding traffic on the airport surface relative to the “own ship” position. The completeness of this surveillance picture (i.e. % of traffic display) is dependent on the underpinning technology providing it, and, as such, may not be wholly accurate.

Various other types of systems may attempt to supplement reality by using additional data feeds from sensors attached to the aircraft (e.g. forward looking infrared (FLIR)).

Text displays can also be used – in particular to convey the messages broadcast by datalink to the flight crew. These may, for instance, indicate the route to be followed by a particular mobile.

**Heads up displays:** These systems are currently not widely deployed on in-service commercial aircraft. However in improving the situational awareness of the mobile operator on the airport surface the development of such systems are seen as a vital step [1][2][3]. They may be used to communicate the position of the aircraft and surrounding traffic on the airport surface to the flight crew (augmenting reality) and advise of what steps the crew should take to resolve the any conflicts encountered.

**Aural alerts:** should be introduced in mobiles, flight crews and drivers will not look at the EFB/ Cockpit Display of Traffic Information (CDTI) at all the times. In vehicles audio alerts could be combined with visual to overcome issues of noise generated from the operating environment.
**Ground movement phases: Vehicles**

Surface vehicles are typically confined to particular areas of the airport surface, depending upon what role they are required to perform. A particular group of vehicles will be concerned with the processes associated with aircraft turn-around. These will include, for example, passenger shuttle transfer buses, refuelling trucks, catering vans and luggage trolleys. They will predominantly operate on the apron area, adhering to limited routings across it and will typically stay close to the terminal buildings.

Other vehicles will be required to roam further afield – venturing out onto the taxiway system and crossing airport runways. Such vehicles may be engaged in bird scaring operations, collecting surface debris and de-icing operations for example. Towing vehicles may also be used to transport aircraft to maintenance facilities.

**Ground movement phases: Aircraft**

**Apron movements:** These areas of the airport surface can be highly congested; incidents connected to this area include wingtip collisions, vehicle collisions with parked aircraft, pushback collisions (and entry into gate). Once pushed back from the gate aircraft may only move in a forward direction unless they are under tow. Therefore, situations where aircraft directly face each other along a single taxiway or congested apron can be resolved only by towing.

**Taxiing:** The size of modern commercial air transport aircraft means they carry with them significant momentum when moving around the airport surface, and as such stopping may prove problematic unless low surface movement speeds are used. These will generally be employed in areas of the taxiway system where multiple routes intersect – higher speeds may be used by aircraft when entering/exiting runways (to minimise their runway occupancy time). Queues will tend to form on the taxiway system around the entry points to runways.

**Take-off roll:** Multiple line ups may be used on the runway itself but once an aircraft commences a take-off or landing that runway should be vacated by all other mobiles. Take-off roll covers the period from which an aircraft is lined up on the runway to the point at which it lifts off the airport surface (i.e. the point at which the aircraft reaches its rotation speed, “Vr”, [velocity ‘r’]: this is the speed at which the aircraft’s nose wheel leaves the ground) (see [5] and [6]).

**Initial climb /Final Approach:** Movements during this phase of flight may be considered by runway incursion protection algorithms (i.e. triggering a warning when an aircraft has begun its climb away from the surface or is yet to land and conflicts with a mobile on the runway surface area).

**Landing roll:** Period of flight from where the aircraft touches down on the airport surface until it exits the runway (its runway occupancy on landing), either via a high or low speed taxiway (see section 2.2 of [4] also references [5] and [6]).
5.2.3. (Mobile 1) Non-conformance to ATC instructions and procedures

General description and inputs

The system warns the mobile when it has departed from the route assigned to it by the ATM system. This routing will typically be specified by the instructions and clearances provided by the ATCO. In addition, this option covers non-conformance to procedures.

Input: The deviation of a mobile from a route assigned to it by the ATM system includes situations when the:

- Mobile moves without receiving the appropriate clearance; and
- Mobile navigates off route in error.

In addition, this option includes the deviation of a mobile from standard operating procedures (e.g. excessive taxi speed).

The detection of deviation from clearances/procedures will require the following inputs to the system:

- The cleared routing of the mobile; and
- The current location of the mobile.

Generic system architecture

This sub-section provides a generic, high-level and technology independent description and diagram of a system architecture that could support this concept of operation. The same template for the system architecture is used in all the descriptions of all the operational concepts throughout this document to show where the differences between them lie. The diagram specifies what information is communicated, its source (i.e. the entity on the airport surface to which it relates) and final destination. This generic description is then developed further in the next sub-section by specifying what systems, currently either in use or development today, could be used to enable the operation of the concept.

The safety net function in the mobile works by comparing the ‘cleared routing’ as issued by ATC (either by voice or datalink communication) to the current location of the surface mobile (as determined by on-board systems e.g. GPS or Inertial Navigation System (INS)). The comparison performed by the system between these two information items is shown in the diagram below by the dashed blue box that surrounds both of them. No other information elements (white boxes) or entities on the airport surface (grey boxes), other than the tower (which provides routing information to the mobile) and the mobile concerned (Mobile 1 in this case, which determines its own location) are involved.
The safety net which would detect the deviation of a mobile from standard operating procedures (e.g. excessive taxi speed) requires the set of rules defining operating procedures (e.g. nominal taxi speed on specific taxiway) to operate.

**Benefits**

- **General benefits** in Section 3.4 apply to this concept. More precisely, the benefit is reduced risk (through appropriate and timely mitigation) and increased efficiency on the airport surface.

- **Rapid response.** The main benefit of this operational concept would be the rapid response of the actors directly involved. Presenting an alert directly to the flight crew is likely to lead to the quickest reaction to the hazardous situation, as the flight crew/vehicle driver is the actor who has to implement the required action.

**Technological enablers**

This sub-section specifies what systems, currently either in use or development today, could be used to enable the operation of the Mobile 1 concept.

Information required includes:

The cleared routing of the mobile via:

- Radio communication clearances (e.g. voice recognition technology, flight crew input of clearances into electronic flight management system); and

- Data-link TAXI (D-TAXI; possibly a Contract bAsed ATm System - CAATS).

The current location of the mobile via:

- Inertial Navigation System (INS);
• Global Positioning System (GPS)/Global Navigation Satellite System (GNSS)/Satellite Based Augmentation System (SBAS)/Ground Based Augmentation System (GBAS), with a moving map on board;

• TIS-B transmission from Surface Movement Radar (SMR) and/or multilateration systems (MLAT).

Constraints and limitations

It can be assumed that human factor issues typical of such systems will continue to exist (e.g. wrong data input). Before the system becomes operational, safety cases should identify a range of potential hazards and ways in which they can be mitigated.

Several constraints and limitations are identified within this concept:

• **Local view only.** Flight crew only has a local overview of the situation, meaning there is no guarantee that they will follow a course of action that is the overall best solution to the hazardous situation. Although the main aim is to safely resolve the hazardous situation, even if this is not through the ‘overall best solution’, there is a minor risk that the flight crew’s choice may lead to a new hazardous situation, e.g. the aircraft might divert from its course to avoid a hazardous situation and move into the path of another mobile.

• **Equipage requirement.** Presentation to flight crew/vehicle drivers puts requirements on aircraft/vehicle equipage.

• **The visibility** on the airport surface will impact the ability of the mobile operators to see any warning issued to them from the surface lighting system.

Assumptions

General assumptions in Section 3.4 apply to this concept.

Problems and risks identified

• **Consistency of alerts presented to different actors.** As there are potentially several flight crews and vehicle drivers active on the airport movement area at any one time during operational hours, alerts may be presented in more than one mobile. If a conflict involves more than one mobile, several situations may occur:

  o All flight crews and drivers are alerted by a consistent alert. Although this is likely to be the desirable situation, there is still a small chance that they will take conflicting actions.

  o Alerts provided to flight crews and drivers involved are not consistent. Before consequences of this situation are considered in more detail, further study into the level of inconsistency may be necessary: alerts are unlikely to present completely different ‘pictures’ of the situation.

  o Alert is not presented to all flight crews and drivers involved. This situation can have several consequences: on the one hand, at least one of the mobiles involved will not be alerted to a particular situation and therefore is unlikely to react to resolve the hazardous situation, on the other hand the likelihood of mobiles taking contradicting action is lower. Although the former of these two points is likely to be more significant, further study will be required to determine the exact impact of this situation.
In relation to this point, the practical implementation of this concept may be considered:

- One option is to present the alert through lighting systems on the airport surface. This has the benefit of all mobiles involved receiving a consistent alert, there is no need for any onboard equipage, but the reliance on equipment on the airport surface may limit the number of areas covered by the system. The amount of information that can be provided will also be limited.

- The other option is to present the alert in the cockpit or vehicle cab. In this case, the risk of inconsistency exists, there is a dependency on equipage, but on the other hand the area and types of conflicts that can be covered will be much higher, and depending on level of sophistication of the implementation, additional information can be presented to help safely resolve the situation.

- **On-board alerting systems.** Very high integrity required by pilots, consequence of false alerts (aborted take-off, missed approach) is a major concern.

- **Integration.** Integration of A-SMGCS and AGL will impose significant costs in terms of:
  - the cost of technical interface with A-SMGCS to provide alerts;
  - the cost of developing/revising operational procedures; and
  - the cost of training for controllers/flight crew/vehicle drivers.

5.2.4. (Mobile 2) Conflicting ATC clearances

An option of airport a safety net which warns the mobile, when a clearance by ATC addressed to it conflicts with another clearance previously issued to another surface mobile, is not realistic. This was decided in the stakeholder workshop which discussed the operational concept, requirements and typical operational scenarios for airport surface safety nets.

5.2.5. (Mobile 3) Infringement of restricted/closed areas

**General description and inputs**

The system warns the mobile operator that either a cleared route or a current position is not safe (e.g. because the route travels through a restricted part of the surface).

It is important to point out that this option is more pertinent to vehicles than aircraft.

**Input:** A restriction on the surface prevents the cleared route from being followed. This includes situations where the mobile:

- Enters into a restricted area,
- Comes into conflict with another mobile through:
  - The presence of another mobile, or
  - The conflicting intent of another mobile.
The detection of infringement will require the following inputs to the system:

- The cleared routing of mobile(s) concerned;
- The current location and/or intent of mobile(s) concerned;
- The current location and/or intent of surrounding surface traffic; and
- The location of inaccessible areas on airport surface.

**Generic system architecture**

The safety net would work by either:

- Comparing the current location and short term intent of the mobile to:
  - the location of restricted areas; and/or
  - the surrounding traffic position.

- Comparing the cleared routing to the location of restricted areas (NB: it is thought to be an impractical proposition for a safety net to be based on a comparison between a *cleared* routing of a mobile and the current surrounding traffic position because the latter quantity is highly dynamic).

The comparisons between these different information sources are shown diagrammatically by the blue dashed boxes surrounding some of the information elements in Figure 5 below. As in the previous functional architecture diagram (Figure 4) only information about the mobile’s cleared routing is provided by the tower to the on-board safety net system.

Information about the ‘restricted areas’ on the airport surface and the location/short intent of surrounding traffic is also communicated to the mobile concerned. It should be re-emphasised at this point that the generic functional architecture only specifies what the information relates to (its ‘source’) and what the final destination of that piece of information is. How it is communicated through the system is not specified. Therefore, for example:

- Information about the location/short intent of the surrounding traffic may be gleaned by SMR radar returns which upon being transmitted to the ATC system in the tower are relayed via datalink back out to safety net systems in the mobiles moving on the airport surface.

- Similarly information about restricted areas on the airport surface may well originate from the tower (information on the area and duration covered by the restriction could be held in an ATC database, for example). However it could also be conceived that this information might be provided by a transmitter placed on the airport surface that directly broadcasts this information to all traffic.
Benefits

See section 5.2.3.

Technological Enablers

This sub-section specifies what systems, currently either in use or development today, could be used to enable the operation of the Mobile 3 concept. In addition to the information elements required for the Mobile 1 concept current location of surrounding traffic and the location of inaccessible areas on the airport surface are required.

The current location of surrounding surface traffic:

- TIS-B uplink feed from ground surveillance systems (e.g. SMR or MLAT systems):
  - SMR will detect all mobiles regardless of transponder equipage as radar is based on primary returns from aircraft (i.e. reflections from the aircraft’s skin), and
  - MLAT tracking of transponder equipped aircraft and vehicles on airport surface.
- ADS-B enables mobiles equipped with ADS-B to be detected and identified by all parties capable of receiving them.
  - Standards for Airborne Traffic Situational Awareness on the airport surface (ATSA-SURF) via a CDTI using ADS-B are currently under development [4].

The location of inaccessible areas on the airport surface:

- Database system 'blocking out' areas of the airport surface;
- Transponder returns (of vehicles operating in restricted area, e.g. construction vehicles); and
- D-ATIS data linked information about inaccessible areas on the airport surface (textural advisory).
Constraints and limitations

See section 5.2.3. and:

- **Exclusion criteria.** The system needs to exclude all maintenance vehicles (e.g. working on the closed runway) from the constant Levels 1 and 2 alerts.

Assumptions

General assumptions in Section 3.4 apply to this concept.

Problems and risks identified

In addition to section 5.2.3.:

- **Impact of flight crew or ATCO error.** Independent of whether the alert is the result of a mobile or ATCO error, the effect of presenting an alert to a mobile will depend on the ability of the flight crew/vehicle driver to recognise the details of the error. If it is clear that, for example, the aircraft under their control is about to enter a restricted area or come into conflict with another mobile, the flight crew will be well placed to address the situation. If it is not clear what the problem is, it may be more difficult.

- **Operational issues:**
  - Rate of false/nuisance alerts: due to incorrect detection of aircraft movements (turns), and
  - Determining the threshold between the triggering of Level 1 and Level 2 alarm.

5.3. TOWER BASED

Figure 6: The operational environment of towers – the ATCO working position
5.3.1. Operational context

The controllers maintain a continuous watch on all flight operations on and in the vicinity of an aerodrome as well as vehicles and personnel on the manoeuvring area. This is carried out through visual observation, augmented as necessary by a suitable surveillance system. The tower ATCO is responsible for operations on the runway and aircraft flying within the area of responsibility of the aerodrome control tower. The ground ATCO is responsible for traffic on the manoeuvring area with the exception of runways.

Consequently, ATCO based surface safety nets are system wide alerts – i.e. they include all airport traffic operating on the airport surface (however they may be limited to given critical areas of the airport surface or to areas of responsibility).

In responding to an alert from an airport surface safety net the ATCO is required to:

- Detect the alert (by aural and displayed alert, regardless of visibility);
- Identify situation concerned and mobiles involved (including their identification/call sign);
- Resolve conflicts; and
- Implement of the resolution through the provision of necessary instructions to the actors involved (note: the ATCO taking no action may be a valid resolution).

5.3.2. Operational environment

The Tower

Visual: The most important aspect of the environment used by ATC to control traffic on the airport surface is still direct visual contact. However, considering the scale of some modern airports, even the direct view of the manoeuvring area can have shortcomings, e.g. due to distance or airport constructions obscuring part of the relevant area. A very important aspect of visual concept is the visibility condition at the airport, i.e. meteorological conditions can severely reduce the ability to directly observe the airport surface. In some cases, there may be cameras at remote locations on the airfield to help with this (e.g. at runway ends). Virtual tower (heads up) displays may also help to provide additional situational awareness to the ATCO.

Any safety net must work the same way regardless of visibility. The modern way of controlling ground traffic is to have a radar display where you can concentrate on all your traffic at the same time and not looking out so much in different directions. Looking out of the window is more for tower ATCOs.

Ground lighting (taxiway-sections, directions and intensity) should be displayed in tower (on a special screen or integrated on the traffic display screen).

Heads down displays: In addition to visual observation, the traffic situation will typically be presented on the traffic display of the ATCO working position, using data from the airport’s surveillance system as input. Different technologies are available for the surveillance system, and each technology can have different characteristics in terms of available data (e.g. mobile position, identification) and data quality (e.g. accuracy and integrity of the position report).

Flight progress board with electronic strips are today very common and could have simple safety net functionality. The electronic strips could also reflect the traffic display and vice versa, i.e.
input on an electronic strip will trigger the same information on the label and label input will update electronic strip.

**HMI Alert types**: Audio, Visual, Audio and Visual, resolution advisories. NUP II+ simulations have shown that aural alert must be implemented to alert the ATCO. Many situations occur in low traffic when ATCOs are less active/observant than under normal situations.

**Other displays and future developments**: ATC will also have additional information available on individual flights, in particular the high level intent of movements (e.g. which parking stand or departure runway an aircraft is moving towards) and which clearances have been issued. The level of sophistication of the technology behind such information may vary, in particular in terms of how far systems are automated and integrated – this may include aspects of System Wide Information Management (SWIM).

**Ground movement phases**

**Apron movements**: Apron ATCOs are responsible for navigating aircraft from the departure gate out to the taxiway system whilst safety negotiating other surrounding mobiles.

**Taxiing**: Ground ATCOs coordinate movements across the taxiways. They principally issue routings to aircraft taxing out or returning from the runway however his area of responsibility also covers the coordination of mobiles transiting across taxiways (including surface vehicles and aircraft). Note: the ground ATCO may also be responsible for apron movements depending on the complexity and density of the traffic flow across the airport surface.

**Final Approach/Landing Take-off Initial climb**: The runway ATCO is responsible for issuing landing, line-up and hold and take-off clearances. They are also responsible for issuing runway crossing clearances. These may be coordinated by the traffic contacting the ATCO directly on a different frequency than the ground ATCO or by the ATCOs coordinating runway crossings in the tower (see sections 1.3 and 2.2 [4], [6], [7], [8] and [9]).

5.3.3. **(ATCO 1) Non-conformance to ATC instructions and procedures**

**General description and inputs**

The system warns the ATCO that a mobile is deviating from the routing issued to it by the ATM system (generally specified by the ATCO’s instructions) by detecting when a mobile has departed from the route assigned to it. In addition, system warns ATCO that a mobile is in non-conformance to operating procedures.

The standard procedures used by ATCOs when moving traffic around surface (specified by the local operations manual) will dictate what clearances are issued and at what time.

**Inputs**: The deviation of a mobile from a route assigned to them by the ATCO includes situations when the:

- Mobile moves without receiving the appropriate clearance; and
- Mobile navigates off route in error.
In addition, this option includes the deviation of a mobile from standard operating procedures (e.g. excessive taxi speed).

The detection of deviation from clearances/procedures will require the following inputs to the system:

- The cleared routing issued by the ATCO; and
- Current position of surface mobiles (i.e. surveillance data of airport surface traffic) with which clearances can be correlated.

The alert will be presented either to a single actor with a global overview or possibly many ATCOs if the scope of the safety net covers multiple areas of responsibility. Areas on the airport surface that transcend multiple areas of ATCO responsibility include, for example, the interface between the runways and surrounding taxiways.

This concept will be achieved by comparing the routing issued by the ATCO (or ATM system) with the cleared routing as reported back by the mobile (verification of what was communicated).

**Generic System architecture**

The safety net function works by comparing the ‘cleared routing’ as issued by ATC to the flight crew (either by voice or datalink communication) to the current location of the mobile.

This requires the ATCO to input the cleared route into a tower based safety net system (a process which could be facilitated via an automatic voice recognition system for example). The current position of the surface traffic must be provided to the safety net as well. This information could, for example, be gathered from SMR returns or via MLAT surveillance. The safety net function is shown in the diagram below by the dashed blue box surrounding both of these information elements in the tower.
Benefits

- **General benefits** in Section 3.4 apply to this concept (i.e. the benefit is reduced risk and increased efficiency on the airport surface).

- **Global overview.** Presenting the alert to someone with a global overview, who can therefore also decide on a globally optimal solution, i.e. there is limited or no risk of actions being taken that lead to new hazardous situations.

- **Consistency of alerts presented to single actor.** Consistency of alerting is not expected to be a very large problem if the alert is presented to the ATCO.

Technological Enablers

This sub-section specifies what systems, currently either in use or development today, could be used to enable the operation of the ATCO 1 concept.

The routing issued by:

- **ATCO tools** (displaying suggested route for mobile on airport surface to the ATCO). These can be based on either surface movement optimisation algorithms or ATCO inputs (e.g. the use of Electronic Flight Strips - EFS).

The cleared routing of the mobile(s) concerned:

- Radio communication clearances read back (e.g. voice recognition technology, flight crew input into electronic flight management system); and

- **D-TAXI.**

The current location of surface mobile(s) concerned:

- Fused or single source surveillance feed from:
  - SMR that will detect all mobiles regardless of transponder equipage as radar is based on primary returns from aircraft (i.e. reflections from the aircraft's skin), and/or
  - MLAT systems that is tracking of transponder equipped aircraft and vehicles on airport surface.

- GPS/GNSS/SBAS/GBAS and ADS-B;

- Radio communication clearances (e.g. voice recognition technology, flight crew input into electronic flight management system).

Constraints and limitations

- **ATCOs workload.** Introduction of this concept may require of ATCO some additional communication since they will be required to provide resolution advisories to the flight crews/vehicle drivers involved. Hence, this may potentially impact ATCOs workload.

Assumptions

General assumptions in Section 3.4 apply to this concept. In addition, with regards to EFS system, the following set of preliminary assumptions applies:
• All controller instructions/clearances are imputed in the EFS system. Otherwise the proposed solution (independent from others) will be futile; and
• There are established operational procedures for input of taxiway clearances into EFS.

Problems and risks identified

• **Conflict involving more than one ATCO.** There is a need to further investigate an issue when the hazardous situation involves mobiles under the responsibility of different ATCOs (however, this may be considered as minor issue).

• **Need for additional communication.** Presenting an alert to a controller means that the system does not directly warn the mobiles involved. This means that there is a need to communicate required resolution advisories to the actors capable of performing actions before the safety net can take effect. This could potentially be a relatively time consuming process that will delay any action being taken to resolve situation and could therefore make it more critical. Additional step required for ATCO communicating any actions to the flight crews/vehicle drivers involved, may impact ATCOs workload.

• **Impact of ATCO error.** It is difficult to say at a generic level what the effect of presenting to an ATCO will be if the alert is caused by an ATCO error. The ATCO may immediately recognise the error and correct it, he might also have difficulty identifying the problem as all mobiles are likely to behave as expected.

• **Integration.** Integration of A-SMGCS and EFS will impose significant costs in terms of:
  - the cost of installation of vehicle transponders;
  - the cost of technical interface with A-SMGCS to provide the ATC clearances;
  - the cost of developing/revising operational procedures; and
  - the cost of training for controllers.

• **Impact of flight crew/vehicle driver error.** If the alert is caused by a mobile error, the ATCO should be well placed to resolve the situation, as the error should be recognisable as a deviation from the expected traffic situation, the ATCO’s ‘mental picture’. However, in order for ATCO to take necessary action timeliness of the alert is essential.

5.3.4. (ATCO 2) Conflicting ATC clearances

General description and inputs

The system warns the ATCO that two or more mobiles have been provided with conflicting clearances. The system detects a) what clearances have been given and b) whether they conflict or not. Parameters for triggering the safety net alerting functionality will depend on the local environment – i.e. the layout of taxiways. The safety net will need to be capable of determining what route the mobiles will take to meet the clearances issued.

Inputs: The detection of conflicting ATC clearances will require the following inputs to the system:
• Clearances issued by ATCO to all traffic; and
• Current position of surface mobiles (i.e. surveillance data of airport surface traffic) with which clearances can be correlated.

The alert will be presented either to a single actor with a global overview or possibly many ATCOs if the scope of the safety net covers multiple areas of responsibility.

**Generic system architecture**

The safety net function works by correlating the current position of the surface mobiles, determining their cleared routing (as issued by ATC), comparing all of them to one another and highlighting conflicts.

This requires the ATCO to input the cleared route into a tower based safety net system (a process which could be facilitated via an automatic voice recognition system for example). The current position of the surface traffic to be must also be provided to the safety net. This information could, for example, be gathered from surface movement radar returns or via MLAT surveillance. The safety net function is shown in the diagram below by the dashed blue box surrounding both of these information elements in the tower.

![Diagram of the functional architecture (ATCO 2)](image)

**Figure 8: Functional architecture (ATCO 2)**

NB: this has the same architecture as the “ATCO 1” operational concept, however in this concept the safety net system compares ATC clearances with one another (to check for conflicts). By contrast the comparison performed by the safety net in the “ATCO 1” operational concept is one between current location of the aircraft and the routing that it has been cleared to follow.

**Benefits**

See section 5.3.3.
Technological enablers

See section 5.3.3.

Constraints and limitations

See section 5.3.3.

Assumptions

See section 5.3.3.

Problems and risks identified

See section 5.3.3.

5.3.5. (ATCO 3) Infringement of restricted/closed areas

General description and inputs

The system warns ATCO that either a current position or a short intent of a mobile is not safe (e.g. because another mobile blocks it, or because the route travels through a restricted part of the surface).

Input: A restriction on the surface prevents the cleared route from being followed. This includes situations where the mobile:

- Enters into a restricted area,
- Comes into conflict with another mobile through:
  - The presence of another mobile, or
  - The conflicting intent or routing of another mobile.

The detection of infringement will require the following inputs to the system:

- The cleared routing of mobile(s) concerned;
- The current location and/or intent of mobile(s) concerned;
- The current location and/or intent of surrounding surface traffic; and
- The location of inaccessible areas on airport surface.

Generic system architecture

The safety net would work by either:

- Comparing the current location and short term intent of the mobile to the location of restricted areas;
- Comparing the cleared routing to the location of restricted areas; and
Comparing the current location and short term intent of all traffic (to determine whether any mobile is in conflict with another).

These comparisons are shown by the blue dashed boxes in the functional architecture diagram below.

As with the previously described operational concept (ATCO 1) the current location/short intent of the mobiles on the airport surface could be provided by central ATC surveillance systems (e.g. SMR or MLAT). Similarly the routing issued by the ATCO could be determined using voice recognition technology. Information on restricted areas might, as mentioned in the Mobile 1 operational concept, be held within an ATC database or broadcast from a transmitter situated on the restricted area itself.

**Figure 9: Functional architecture (ATCO 3)**

**Benefits**

See section 5.2.8.

**Technological enablers**

This sub-section specifies what systems, currently either in use or development today, could be used to enable the operation of the ATCO 3 concept. In addition to the information elements required for the ATCO 1 concept, current location of surrounding traffic and the location of inaccessible areas on the airport surface are required.

The cleared routing of the mobile(s) concerned:

- See section 5.3.3.

The current location and/or intent of surface mobile(s) concerned:

- See section 5.3.3.
The current location and/or intent of surrounding surface traffic:

- See section 5.3.3. under ‘the current location and/or intent of surface mobiles concerned’.

The location of inaccessible areas on the airport surface:

- Database system ‘blocking out’ areas of the airport surface on the SMR HMI;
- SMR/transponder returns (of vehicles operating in restricted area, e.g. construction vehicles)

**Constraints and limitations**

See section 5.3.3. and:

- **Exclusion criteria.** The system needs to exclude all maintenance vehicles (e.g. working on the closed runway) from the constant Levels 1 and 2 alerts.

**Assumptions**

See section 5.3.3.

**Problems and risks identified**

See section 5.3.3. and:

- **Operational issues:**
  - Rate of false/nuisance alerts due to incorrect detection of aircraft movements (turns), and
  - Determining the threshold between the triggering of Level 1 and Level 2 alarm.

### 5.4. BOTH ENVIRONMENTS (TOWER AND MOBILE)

**5.4.1. General**

This section describes the operational concept for a single and harmonised safety net functionality that provides outputs to multiple actors. This is distinct from but similar to a situation where multiple individual safety net concepts operated together in parallel.

**5.4.2. (Both 1) Non-conformance to ATC instructions and procedures**

**General description and inputs**

The system warns the ATCO, the deviating mobile itself and the surrounding mobiles that a mobile is deviating from the routing issued to it by the ATM system (generally specified by the ATCO’s instructions) by detecting when a mobile has departed from the route assigned to it. In addition, this option covers non-conformance to procedures.
**Input**: The deviation of a mobile from a route assigned to him by the ATCO includes situations when the:

- Mobile moves without receiving the appropriate clearance; and
- Mobile navigates off route in error.

In addition, this option includes the deviation of a mobile from standard operating procedures (e.g. excessive taxi speed).

The detection of deviation from clearances/procedures will require the following inputs to the system:

- The cleared routing issued by the ATCO; and
- Current position of surface mobiles (i.e. surveillance data of airport surface traffic) with which clearances can be correlated.

**Generic system architecture**

The system architecture (inputs, information flow and information comparisons) for this concept is an amalgamation of the system architecture from the Mobile 1 and ATCO 1 operational concepts. The two sets of information flows will need to be consistent with one another to ensure that all actors receive timely, relevant and reliable alerts that they can be sure have been drawn from a common situational awareness picture.

**Benefits**

- **Distribution of roles and responsibilities.** This option aims to use the advantages of both previous options, whilst addressing and mitigating the disadvantages.
• **Impact of flight crew or ATCO error.** This concept ensures each actor remains “in the loop” in terms of situational awareness. This mitigates the risk of a single actor making an undetected error.

**Technological enablers**

Currently, a surface lighting movement guidance system presents ‘alerts’ to flight crew, vehicle drivers and controllers. The visibility on the airport surface will impact the ability of the mobile operators to see the warning issued to them from the surface lighting system. The ATCO will be ‘alerted’ by the lighting control panel in the tower showing what lighting sequences have been triggered by a safety net functionality. These systems can be configured to provide guidance along a cleared route.

This sub-section specifies what systems, currently either in use or development today, could be used to enable the operation of the Both 1 concept.

The cleared routing of all surface mobile(s):

• Radio communication clearances (e.g. voice recognition technology, flight crew input into EFMS);
• D-TAXI (possibly a CAATS system);
• ATCO tools (displaying suggested route for mobile on airport surface to the ATCO based on either surface movement optimisation algorithms or ATCO inputs – e.g. the use of EFS).

The current location all surface mobile(s):

• Fused or single source surveillance feed e.g. from:
  - SMR that will detect all mobiles regardless of transponder equipage as radar is based on primary returns from aircraft (i.e. reflections from the aircraft’s skin), and/or
  - MLAT systems that are tracking of transponder equipped aircraft and vehicles on airport surface.
• GPS/GNSS/SBAS/GBAS and ADS-B;
• INS;
• ADS-B that enables mobiles equipped with ADS-B squirting transponders to be detected and identified by all parties capable of receiving them.
• Airborne Separation Assistance System (ASAS) on the airport surface (delegation of separation responsibility from ATCO to flight crew) data linked to tower and cleared to perform such delegated manoeuvres.

**Constraints and limitations**

The visibility on the airport surface will impact the ability of the mobile operators to see the warning issued to them from the surface lighting system.

**Assumptions**

General assumptions in Section 3.4 apply to this concept.
Problems and risks identified

- **Distribution of roles and responsibilities.** Clear procedures and roles and responsibilities are required, as the issues relating to overview of the situation and early reaction seem to contradict. The ATCO has the global overview of the situation and will be best placed to define the resolution to a hazardous situation. At the same time, the flight crew or mobile operator is required to implement a resolution. This leads to a dilemma:
  - If the flight crew or mobile operator takes action immediately after receiving an alert, the added benefit of presenting the alert to the ATCO with the global overview is lost.
  - If, after receiving an alert, the flight crew or mobile operator have to wait for instructions from the ATCO, the added benefit of presenting the alert to the flight crew who can take early action is lost.

- **Operational constraints:** the use of electronic strips shall be systematic and the content of strips shall be un-ambiguously interpreted by the automated system (all clearances for aircraft in or at the proximity of active runways) [13].

- **Integration of A-SMGCS and AGL.** Integration of A-SMGCS and AGL will impose significant costs in terms of:
  - the cost of technical interface with A-SMGCS to provide alerts;
  - the cost of developing/revising operational procedures; and
  - the cost of training for controllers/flight crew/vehicle drivers.

- **Integration of A-SMGCS and EFS.** Integration of A-SMGCS and EFS will impose significant costs in terms of:
  - the cost of installation of vehicle transponders;
  - the cost of technical interface with A-SMGCS to provide the ATC clearances;
  - the cost of developing/revising operational procedures; and
  - the cost of training for controllers.

5.4.3. (Both 2) Conflicting ATC clearances

General description and inputs

The system warns the ATCO and the threatened mobiles (i.e. those in a “potentially hazardous situation”) that mobiles will come into conflict if they follow the clearances given to them by ATC.

**Inputs:** The detection of conflicting ATC clearances will require the following inputs to the system:

- Clearances issued by ATCO to all traffic; and
- Current position of surface mobiles (i.e. surveillance data of airport surface traffic) with which clearances can be correlated.
The alert will be presented either to a single actor with a global overview or possibly many ATCOs if the scope of the safety net covers multiple areas of responsibility.

**Generic System architecture**

The system architecture (inputs, information flow and information comparisons) for this concept is an amalgamation of the system architecture from the Mobile 2 and ATCO 2 operational concepts. The two sets of information flows will need to be consistent with one another to ensure that all actors receive timely, relevant and reliable alerts that they can be sure have been drawn from a common situational awareness picture.

![Figure 11: Functional architecture (Both 2)](image)

**Benefits**

See section 5.4.2.

**Technological Enablers**

See section 5.4.2.

**Constraints and limitations**

See section 5.4.2.

**Assumptions**

See section 5.4.2.

**Problems and risks identified**

See section 5.4.2.
5.4.4. (Both 3) Infringement of restricted/closed areas

General description and inputs

The system warns the ATCO, the threatened mobile themselves and the surrounding traffic either a cleared route or a current position of a mobile is not safe (e.g. because the route travels through a restricted part of the surface).

Input: A restriction on the surface prevents the cleared route from being followed. This includes situations where the mobile:

- Enters into a restricted area,
- Comes into conflict with another mobile through:
  - The presence of another mobile, or
  - The conflicting intent or routing of another mobile.

The detection of infringement will require the following inputs to the system:

- The cleared routing of mobile(s) concerned;
- The current location and/or intent of mobile(s) concerned;
- The current location and/or intent of surrounding surface traffic; and
- The location of inaccessible areas on airport surface.

Generic System architecture

The system architecture (inputs, information flow and information element comparisons) for this concept is an amalgamation of the system architecture for the Mobile 3 and ATCO 3 operational concepts. The two sets of information flows will need to be consistent with one another to ensure that all actors receive timely, relevant and reliable alerts that they can be sure have been drawn from a common situational awareness picture.
Benefits

See section 5.4.2.

Technological Enablers

Surface lighting movement guidance system presents ‘alerts’ to the pilot, vehicle driver and the controller (although visibility conditions will determine how clearly this is presented to the mobile operators). These systems can be set up to protect a given area – such as that surrounding an active runway or closed taxiway. Current state of the art systems include aircraft movement activated stop bars and runway entry warning lights that illuminate when an aircraft incurs upon it.

This sub-section specifies what systems, currently either in use or development today, could be used to enable the operation of the Both 3 concept.

The cleared routing of all surface mobile(s):

- See section 5.4.2.

The current location and/or intent of all mobiles:

- See section 5.4.2.

The location of inaccessible areas on the airport surface:

- Database system ‘blocking out’ areas of the airport surface on the SMR HMI;
- SMR/transponder returns (of vehicles operating in restricted area, e.g. construction vehicles);
- D-ATIS data linked information about inaccessible areas on the airport surface (textural advisory);
• TIS-B data linked information (e.g. SMR reflections) of inaccessible areas on the airport surface (geographical location).

Assumptions
See section 5.4.2.

Problems and risks identified
See section 5.4.2.
6. DISCUSSION OF IDENTIFIED OPTIONS

This section summarises the identified options in terms of differences and similarities and advantages and disadvantages. In addition, it gives information about integration of options and what is their relation to the Roadmap.

6.1. DIFFERENCES AND SIMILARITIES

6.1.1. Main concept options

This sub-section summarises the main differences between the eight concepts described in the previous section. The concepts are discussed based on the actor or actors to whom the alert is presented, in line with Sections 5.2, 5.3 and 5.4, and for each of these the effect of the two categories of situations is discussed as relevant.

Presentation of alert to flight crew or vehicle driver only

- **Local view only.** Flight crew only has a local overview of the situation, meaning there is no guarantee that he will follow a course of action that is the overall best solution to the hazardous situation. Although the main aim is to safely resolve the hazardous situation, even if this is not through the ‘overall best solution’, there is a minor risk that the flight crew’s choice may lead to a new hazardous situation, e.g. the aircraft might divert from its course to avoid a hazardous situation and move into the path of another mobile.

- **Quick action by actors directly involved.** Presenting an alert directly to the flight crew is likely to lead to the quickest reaction to the hazardous situation, as the flight crew is the actor who has to implement the required action.

- **Equipage requirement.** Presentation to flight crew or vehicle driver puts requirements on aircraft/vehicle equipage.

- **Consistency of alerts presented to different actors.** As there are several flight crews and vehicle drivers active on the airport movement area at any one time during operational hours, alerts may be presented in more than one mobile. If a conflict involves more than one mobile, several situations may occur:
  
  - All flight crews and drivers are alerted by a consistent alert. Although this is likely to be the desirable situation, there is still a small chance that they will take conflicting actions.
  
  - Alerts provided to flight crews and drivers involved are not consistent. Before consequences of this situation are considered in more detail, further study into the level of inconsistency may be necessary: alerts are unlikely to present completely different ‘pictures’ of the situation.
  
  - Alert is not presented to all flight crews and drivers involved. This situation can have several consequences: on the one hand, at least one of the mobiles involved will not be alerted to a particular situation and therefore is unlikely to react to resolve the hazardous situation, on the other hand the likelihood of mobiles taking contradicting action is lower. Although the former of these two points is likely to be more significant, further study will be required to determine the exact impact of this situation.

  In relation to this point, the practical implementation of this concept may be considered:

  - One option is to present the alert through lighting systems on the airport surface. This has the benefit of all mobiles involved receiving a consistent alert, there is no need for any
onboard equipage, but the reliance on equipment on the airport surface may limit the number of areas covered by the system. The amount of information that can be provided will also be limited.

- The other option is to present the alert in the cockpit or vehicle cab. In this case, the risk of inconsistency exists, there is a dependency on equipage, but on the other hand the area and types of conflicts that can be covered will be much higher, and depending on level of sophistication of the implementation, additional information can be presented to help safely resolve the situation.

**Impact of flight crew or ATCO error.** Independent of whether the alert is the result of a flight crew or ATCO error, the effect of presenting an alert to a flight crew will depend on the ability of the flight crew to recognise the details of the error. If it is clear that, for example, the own aircraft is about to enter a restricted area or come into conflict with another mobile, the flight crew will be well placed to address the situation. If it is not clear what the problem is, it may be more difficult.

**Presentation of alert to ATCO only**

- **Global overview.** Presenting the alert to someone with a global overview, who can therefore also decide on a globally optimal solution, i.e. there is limited or no risk of actions being taken that lead to new hazardous situations.

- **Conflict involving more than one ATCO.** Possible exception to the previous point might be if the hazardous situation involves mobiles under the responsibility of different ATCOs (however, this may be considered as minor issue).

- **Need for additional communication.** Additional step required for ATCO communicating any actions to the flight crews/vehicle drivers involved, which will take up some time in a situation where quick action may be critical.

- **Consistency of alerts presented to single actor.** Consistency of alerting is not expected to be a very large problem if the alert is presented to the ATCO.

- **Impact of ATCO error.** It is difficult to say at a generic level what the effect of presenting to an ATCO will be if the alert is caused by a ATCO error. The ATCO may immediately recognise the error and correct it, he might also have difficulty identifying the problem as all mobiles are likely to behave as expected.

- **Impact of flight crew/vehicle driver error.** If the alert is caused by a flight crew error, the ATCO should be well placed to resolve the situation, as the error should be recognisable as a deviation from the expected traffic situation, the ATCO’s ‘mental picture’. However, in order for ATCO to take necessary action timeliness of the alert is essential.

**Presentation of alert to both ATCO and flight crew/vehicle driver**

- **Distribution of roles and responsibilities.** This option aims to use the advantages of both previous options, whilst addressing the disadvantages. To achieve this goal, clear procedures and roles and responsibilities are required, as the issues relating to overview of the situation and early reaction seem to contradict: As a ATCO has the global overview of the situation, he will be best placed to define the resolution to a hazardous situation, but at the same time, the flight crew is the one who has to implement a resolution. This leads to a dilemma:

  - If the flight crew takes action immediately after receiving an alert, the added benefit of presenting the alert to the ATCO with the global overview is lost.
• If, after receiving an alert, the flight crew has to wait for instructions from the ATCO, the added benefit of presenting the alert to the flight crew who can take early action is lost.

- **Impact of flight crew or ATCO error.** This effectively mitigating against a single actor making an error by raising the situational awareness of all actors.

### 6.1.2. Impact of input and safety net location

Identification of advantages and disadvantages as presented in the previous section can not be seen completely independently from the architecture and implementation of the safety net. Some examples were already addressed in the previous section, e.g. whether an alert is presented to a flight crew via onboard equipment or warning lights placed on the airport surface. Focussing on the simplified architecture of the surface safety net (Figure 1):

#### Input used

Considering safety net functions that are part of onboard systems two input options can be considered:

- **Use of ATC surveillance function information**
  - **Single consistent view.** A single view of traffic information will be used by all actors involved. Multiple inputs from different systems/technologies can be used to develop this view.
  - **Quality of information.** The quality of the traffic information depends on the local surveillance system and may suffer from any shortcoming this may have: lack of coverage, lack of certain data (e.g. identification), degradation of service.
  - **Limited dependency on aircraft equipage.** The ATC surveillance function will have a limited dependency on equipage (possibly, an airport multilateration system will require transponder equipage).

- **Use of mobile-to-mobile traffic information.** (assumed to be only relevant for onboard systems)
  - **Potentially inconsistent view.** There is a risk of inconsistency of traffic information used by different mobiles.
  - **Equipage.** This approach requires a certain level of equipage of mobiles, with any mobiles that are not properly equipped not being included in the traffic information used by the safety net function.

- **Use of both mobile-to-mobile and ATC surveillance traffic information** was not considered a separate option as generally the surveillance picture presented to ATC will be the more complete.

A safety net function that is part of the ATC system is assumed to always use ATC surveillance data as its input. When considering only onboard systems, data can be gleaned either from the sensors onboard the aircraft or from a central ATC source.

The use of ATC surveillance data by all onboard safety nets allows the use of the same traffic information thereby increasing probability of consistent alerting. However if the onboard safety net functions rely on different alerting criteria there is still a chance of inconsistent alerting even with the same inputs.
Location of safety net function

- **Safety net as part of the ATC system**
  - **Consistency.** In this option, there is a single safety net function with single output.
  - **Flexibility.** Safety net parameters can be set in a flexible way in relation to airport operational circumstances, e.g. low visibility.
  - **Information on environment.** A safety net that is part of the ATC system would have easy access to other information on the operational environment that may be relevant to the safety net, e.g. active runways, (temporary) restricted areas.

- **Safety net as part of the onboard system**
  - **Potential inconsistency.** Potentially large number of safety net functions active on the airport surface, potentially using different sets of inputs. Different functions can come to different conclusions regarding level of hazard of a specific situation (even when functions use the same inputs: different algorithms or parameters settings may apply).
  - **Equipage.** The system wide effectiveness of the safety net requires as close to 100% equipage as possible. Further, although the safety of any given mobile on the surface may be enhanced by their own equipage (e.g. by raising the situational awareness of the operator) this protection will be limited. The need for high equipage will be particularly driven by safety net function that requires a position feed from all surface threats (mobiles) (e.g. via ADS-B).
  - **Use of multiple safety nets at one location.** As mentioned above this situation could ultimately lead to inconsistent alerting and resolution advisories being issued to various different actors either because of differences in the surveillance data feed provided to it or differences in the control algorithms. Ultimately the occurrence of such a situation would have to be allowed for in the local procedures employed on the airport surface. These procedures would need to detail which resolution advisory to follow – e.g. that issued by a) the mobile’s warning system or b) that offered by the ATCO.

### 6.2. INTEGRATION OF CONCEPTS AND ROADMAP

Relationship of stepped development of the candidate safety nets, proposed within the Roadmap, and operational concepts proposed in Section 5 is shown in Figure 13.

For example, Ground-Based category presents an extension of A-SMGCS Level 2 system, making detection of runway incursion precursors and hazardous situations on taxiways possible. Alerts are presented to ATCOs and direct notification of alerts to mobiles is given by airport ground lighting (AGL) system. Therefore this safety net will be covered by considering combination of all Mobile and ATCO concepts.

This was just an example to show that the different concepts discussed do not necessarily lead to a single optimal direction for development. Situations such as a combined implementation of complementary options, or an evolutionary development in which initially a higher mature but lower performance concept is chosen, are possible.
6.3. INITIAL REQUIREMENTS

Initial requirement may include:

**Consistency of alerting**

**Requirement:** Single safety net function for whole airport

**Notes:** Individual safety nets for individual aircraft/vehicles result in a risk of inconsistency. Some mitigation of this risk may be available in that, unlike some other options, all aircraft use the same input (as provided by the ground system).

**Globally optimal solution**

**Requirement:** Single system ensuring a safe, orderly and expeditious flow of surface traffic (of which a surface safety net would be a part).

**Notes:** Multiple decision makers are involved in controlling surface vehicles (ATCOs, flight crews and vehicle drivers). Some mitigation in the fact that they will all base their decisions on the same traffic information, but not necessarily on the same alert (in fact it is not even guaranteed they will all get an alert at all).

**Time from alert to resolution**

**Requirement:** There needs to be an appropriate time from incident to alert so that operator can take avoiding action.

**Notes:** Alerts to ATCOs are time consuming due to the intermediate step (communication of actions from ATCO to flight crew) being required. Comparatively, alerts presented to mobile operators allow a relatively quick response.
7. TECHNOLOGICAL ENABLERS

This section starts with a summary of existing operational procedures or systems aimed at preventing the hazardous situation at airport surface. This is followed by presentation of required technological enablers sought by the Roadmap. Finally this section gives information about maturity of technology identified in previous sections and provides extension to the technological enablers analysis given in the Roadmap.

7.1. EXISTING SAFEGUARDS

7.1.1. Category 1: Non-conformance to ATC instructions/procedures

Deviations from ATC clearances by flight crew or vehicle drivers in the proximity of active runways can be currently mitigated by:

- read-back of ATC clearances,
- sterile cockpit for runway movements, and
- A-SMGCS Level 1 (surveillance service).

If flight crew or vehicle drivers get disoriented and confused about their position or the next taxiway segment to follow several existing safeguards are available:

- visual navigation aids mandated by ICAO Annex 14 (e.g. panels, markings, lights on taxiways, runways or service roads),
- hot-spots maps,
- training for vehicle drivers, and
- A-SMGCS Level 1 (surveillance service).

7.1.2. Category 2: Conflicting ATC clearances

The issue of conflicting clearances by ATCOs can be currently mitigated by:

- A-SMGCS surveillance service, and
- Flight strips (paper or electronic).

7.1.3. Category 3: Infringement of restricted or closed areas

Hazardous situations where an aircraft penetrates a restricted or a closed area are mitigated by:

- visual aids for delineating restricted areas,
- digital ATIS information (D-ATIS service but not necessarily covering all closed/restricted areas), and
- NOTAMs.
7.2. TECHNICAL ENABLERS REQUIRED

The set of required technological enablers have been identified within the Roadmap, including the existing systems and current on-going developments as part of European Commission, EUROCONTROL or FAA R&D projects [13]. This section summarises the set of automated systems (and changes to existing ones) required to support the detection and alerting of the different hazardous situations identified during the Roadmap.

7.2.1. Ground systems

The section contains the description of the main ground systems (and changes to) required to enable the detection and alerting of the selected hazardous situations on airport surface.

7.2.1.1. A-SMGCS surveillance (A-SMGCS Level 1)

**Description:** provides the surveillance service to ATCOs, i.e. identification, position and state vector for all cooperative and non-cooperative aircraft and vehicles on the airport movement area.

**New functions added and changes to be introduced:**

- Provision of the surveillance situation to aircraft as part of the TIS-B data link service: to enable the on-board traffic surveillance system, acting as gap filler (position of non-equipped aircraft) and integrity monitor (aircraft broadcasting erroneous position).

7.2.1.2. A-SMGCS alerting (A-SMGCS Level 2)

**Description:** provides the alerting service to ATCOs, i.e. detection and notification of hazardous situations (currently runway conflicts).

**New functions added and changes to be introduced:**

- Detection of pilots disorientation in the vicinity of runways
  - Requires interfacing with the Aerodrome Configuration Management System
- Detection of taxi speed excess, infringement of restricted areas or taxiways
  - Requires interfacing with the Aerodrome Configuration Management System
- Detection of ATC conflicting clearances and mobile deviations from clearances
  - Requires interfacing with the Electronic Flight System
- Alerting to the ATCOs: provision of alerts (Information or Alarm levels) to the ATCO(s) in charge of taxi movements (not only to ATCO in charge runway operations)
- Provision of the surveillance situation to aircraft as part of the TIS-B data link service (gap filler).

7.2.1.3. Aerodrome configuration management system

**Description:** keeps track of the aerodrome geographic information (layout), the active and pre-defined aerodrome configurations, including runway configuration and restricted areas for aircraft movements (e.g. closed runways). Changes are introduced by the Tower Supervisor or assistants.
New functions added or changes to be introduced:

- Restrictions on taxiway usage or standard taxi routes from pre-defined aerodrome configurations or using ATCO input;
- Interfacing with the FIS air-ground data link broadcast system: to ensure the broadcast to flight crews of active aerodrome configurations and restrictions for taxi movements by data link as part of ATIS or NOTAM messages (D-OTIS service).

Note on D-OTIS (Digital Operational Terminal Information Service): covers the provision to flight crews of NOTAMs, ATIS, and VOLMET information through data linked messages.

7.2.1.4. Electronic Flight Strips (EFS) system

Description: The Electronic Flight Strips (EFS) system electronically records the actions taken by controllers that would previously have been written on paper. Therefore it is easy to pass key triggers from EFS to A-SMGCS to give the latter a better picture of the controller’s intentions.

The exact triggers that could be used may include:

- Take off clearance;
- Line up clearance;
- Clearance to enter/cross runway; and
- Landing clearance.

EFS does not record full routing information, so it would not be possible to provide full route adherence monitoring. However, it would be possible to develop rules within the A-SMGCS safety net to take account of the above triggers. For example, following a take-off clearance the runway ahead could be checked to confirm it is clear, allowing a more timely warning than that given by waiting to detect the acceleration of the departing aircraft.

Any rule set developed would have to take into account the current operational concepts at European airports, for example the use of conditional clearances.

New functions added or changes to be introduced:

- Technical interface with A-SMGCS to provide the ATC clearances issued for runway operations (i.e. line-up, take-off, crossing, and landing) and to detect and notify potential operational errors from controllers (issuance of conflicting clearances) or pilots (deviation from the clearance).

7.2.1.5. Aerodrome Lighting Control and Monitoring System (ALCS)

Description: Aerodrome lighting control and monitoring systems could be used for approach, runway, taxiway, and runway guard lights, and for Precision Approach Path Indicators (PAPIs), and stopbars. This includes all individual lighting functions, from PAPI's to taxiway centreline lighting, but also individual signs in the field. Remote control of other external equipment (such as rotating beacons, apron floodlighting, power supply equipment) can be included as well.

The integration of the A-SMGCS lighting systems is currently being assessed by EUROCONTROL. The concept under investigation has two key objectives:
• prevention aiming to reduce the risk of runway incursions; and
• warning aiming to inform pilots that a runway incursion is taking place.

As a result, there are two modes of operation identified:

• The prevention mode aims to raise the awareness of the runway occupancy and thus prevents the occurrence of runway incursion (prevents aircraft and ground vehicles from entering the occupied runway). To achieve this aim, the prevention mode of the A-SMGCS lighting system could use a set of longitudinal lights with a steady red colour (known as preventative lights).
• The incursion mode aims to trigger required emergency actions after a runway incursion occurred and prevent the collision. It is based on triggering a set of longitudinal red flashing lights, called incursion lights.

New functions added or changes to be introduced:

• Interfacing with A-SMGCS alerting service to alert flight crews of runway incursions or runway conflicts.
• Preventative and incursion lights are positioned in the same location on or close to taxiway and runway centrelines. The presentation could be red lighting for the preventative lights and flashing in the case of incursion lights (this should be the subject of further evaluation).

7.2.2. Aircraft Systems

This section lists the required system enablers on-board aircraft, using the system ‘blocks’ proposed by the Roadmap and EMMA-2 research project [13].

7.2.2.1. Surface movement guidance system

Description: provides ownship position with respect to aerodrome layout (e.g. electronic moving map display) or navigation guidance on the airport surface.

Maturity/availability: as a first example of such system, the airport moving map is a feature of the Electronic Flight Bag (EFB) systems that aims to replace paper charts with an electronic display. The airport moving map is available from several EFBs manufacturers but its use by flight crews as a navigation mean requires an airworthiness certification (critical system), which is still under preparation by FAA and EASA.

New functions added or changes to be introduced:

• Surface movement error tracking: using up-to-date aerodrome configuration information from the airport database.

7.2.2.2. Airport database

Description: provides the airport geographical and layout data to on-board applications.

New functions added or changes to be introduced:

• Reception of up-to-date aerodrome configuration data: through data link services (e.g. D-OTIS) made available by the ground system;
• Inclusion of permanent taxiway restrictions or standard taxi routes (as published in AIPs for instance).

7.2.2.3. Traffic surveillance system (Dependent surveillance)

**Description:** provides traffic surrounding the own-ship (identification and state vector of other aircraft and vehicles).

**New functions added or changes to be introduced:**

• Requires a high level of integrity of the traffic situation picture (to lower false alerts rate).

**Maturity/availability:** ADS-B using 1090Mhz is the current standard under development, its use for the traffic surveillance system covers several functions:

• ADS-B-out for the broadcast of aircraft identification and state vector is a standard feature on new aircraft and retrofit solutions exist for most commercial aircraft

• A-SMGCS Surveillance and TIS-B for the broadcast by the ground system of the identification and position of aircraft on the airport surface as:
  o Gap filler: for not-ADS-B-equipped aircraft or airport vehicles (gap filler), standardized in RTCA DO260 and DO260A;
  o Integrity Monitor: reporting faulty aircraft position(s) broadcast and correct position(s) to be used (not standardized);
  o ADS-B-in: is still under research as part of the EUROCONTROL CASCADE programme, potential applications for different phases of flight are being developed and tested, technical standards are expected for 2009.

7.2.2.4. Obstacle proximity detection (Independent surveillance)

**Description:** detects the proximity of static or mobile obstacles in the vicinity of the aircraft.

**Maturity/availability:** This concept is under research. The concept involves Enhanced Vision System (EVS) being used for approach operations (supplements Pilots’ vision for acquisition of runway elements and detection of obstructions). Infra-red sensors are candidate for the detection of obstacles in all visibility conditions (night or low visibility) but need to be further assessed for use during surface movements. Head-up displays combined with infra-red sensors are used currently as part of Enhanced Vision System (EVS) for precision approach operations (business aviation in North America) and become available for commercial transport in Europe (Amendment of JAR-OPS-1 in progress). The use of such system may also contribute to the safety of low visibility operations but required additional development for the automated detection of obstacles.

**New functions added or changes to be introduced:**

• New function on-board.

7.2.2.5. ATC clearance monitor

**Description:** receives ATC clearances issued for the surface movement of the considered aircraft (taxi and runway movements) and monitors the conformance of own-ship movements on the airport surface.
Maturity/availability: the use of data link services for the reception of ATC clearances issued during surface movements is under research (as part of the EMMA-2 project).

New functions added or changes to be introduced:

• New function on-board.

7.2.2.6. On-board runway conflict alerting

Description: detects potential conflict(s) with other aircraft / vehicles on runways based on traffic situation picture.

Maturity/availability: under research.

New functions added or changes to be introduced:

• New function on-board.

7.3. MATURITY OF TECHNOLOGY OPTIONS IDENTIFIED

The following Table 4 summarises the set of required technical enablers discussed above and in Section 4. It gives an indication of the complexity of the development or changes to existing systems to be made and their availability considering the development steps proposed for the Airport Surface Safety Nets Roadmap (mature/deployed/trial – under development – under research). Furthermore, gives an indication of what type of alert is provided (i.e. aural or visual) and to which actor (i.e. flight/crew/vehicle driver or/and ATCO). Finally, the last column of provides information how technology options are mapped to operational concepts proposed in Section 4.

Table 5 shows runway incursion technology enablers and their availability in terms of maturity, as well as examples of their deployment or trial phase.
### Operational concept & requirements for airport surface safety nets

<table>
<thead>
<tr>
<th>System/Tech Enabler</th>
<th>Model</th>
<th>Complexity of deployment/changes to existing systems</th>
<th>Availability</th>
<th>Status</th>
<th>Alert Pilot/Driver</th>
<th>Alert ATCO</th>
<th>Conops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerodrome Configuration Management System</td>
<td>Electronic Flight Stripping System</td>
<td>Low</td>
<td>Mature</td>
<td>Exists at most medium/ major airports with different levels of evolution (for instance coupled with digital ATIS or not)</td>
<td>✔</td>
<td>✔</td>
<td>ATCO 3</td>
</tr>
<tr>
<td>Airfield Lighting Control and Monitoring</td>
<td>Airfield Lighting Control and Monitoring</td>
<td>Medium</td>
<td>Under development</td>
<td>Examples of semi-automatically switched light segments exist (such as red stop bars connected to magnetic loops)</td>
<td>✔</td>
<td>✔</td>
<td>ATCO 1, ATCO 3</td>
</tr>
<tr>
<td>Surface Movement Guidance System</td>
<td>Electronic Flight Bag (EFB)</td>
<td>Aircraft: Medium (navigation error tracking)</td>
<td>Mature</td>
<td>EFB use by flight crews as a navigation mean requires an airworthiness certification, which is still under preparation by FAA and EASA.</td>
<td>✔</td>
<td>✔</td>
<td>Mobile 1, Mobile 3</td>
</tr>
<tr>
<td>Traffic Surveillance System</td>
<td>Traffic Surveillance System</td>
<td>Aircraft: High</td>
<td>Under development</td>
<td>Currently electronic aerodrome charts are replacing the paper versions as part of EFB applications</td>
<td>✔</td>
<td>✔</td>
<td>Mobile 3, ATCO 3, All 3</td>
</tr>
</tbody>
</table>

---

1 Still under research as part of EUROCONTROL CASCADE programme

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<table>
<thead>
<tr>
<th>System/Technical Enabler</th>
<th>Model</th>
<th>Complexity of deployment/changes to existing systems</th>
<th>Availability</th>
<th>Status</th>
<th>Alert</th>
<th>Conops</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIS-B</td>
<td>runways conflict detection</td>
<td>Visual</td>
<td>Under research</td>
<td>High (under research)</td>
<td>All 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>programme</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obstacle Proximity Detection</td>
<td>Enhanced Vision System (EVS)</td>
<td>High (under research)</td>
<td>Under research</td>
<td>Under research (as part of the EMMA-2 project).</td>
<td>Mobile 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATC Clearance Monitor</td>
<td></td>
<td>High (under research)</td>
<td>Under research</td>
<td>Under research (as part of the EMMA-2 project).</td>
<td>All 1, All 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>On-board runway conflict detection</td>
<td>Aircraft: High (high integrity level required)</td>
<td>Under research</td>
<td>Under development</td>
<td>Under development</td>
<td>Mobile 1-3; All 1-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vehicle: Medium (lower integrity required compared to aircraft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Summarised technological enablers (Source: updated Roadmap)
<table>
<thead>
<tr>
<th>Technology</th>
<th>Model</th>
<th>Complexity of deployment/changes to existing systems</th>
<th>Availability</th>
<th>Status</th>
<th>Alert Pilot/Driver</th>
<th>Alert ATCO</th>
<th>ConOps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local area surveillance</td>
<td>Critical Area Management System (CAMS)</td>
<td>Deployed</td>
<td>Frankfurt (considered by Luton)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Runway Incursion and Debris Detection System (RIDDS)</td>
<td>Under development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Runway occupancy</td>
<td>Ground Marker</td>
<td>Deployed</td>
<td>Concord Buchanan Field, CA. Trials at Bournemouth and Manchester</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Runway Status Lights (RWSL)</td>
<td>Trial</td>
<td>San Diego International Airport, Dallas/Fort Worth International Airport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Autonomous Runway Incursion System (ARIPS)</td>
<td>Under development</td>
<td>Trials at Ted Frances Green Airport, Providence, Rhode Island, USA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cockpit navigation</td>
<td>Runway Awareness and Advisory System (RAAS)</td>
<td>Deployed</td>
<td>6350 runways validated worldwide (see website for database)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electronic Flight Bag (EFB)</td>
<td>Deployed</td>
<td>Airlines and operators worldwide including the UPS and KLM fleets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cockpit navigation &amp; surveillance</td>
<td>PathProx</td>
<td>Under development</td>
<td>Trials at Ohio University Airport - Snyder Field Dallas Fort Worth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Runway Incursion Prevention System (RIPS)</td>
<td>Under development</td>
<td>Trials at Reno/Tahoe International Airport, Wallops Flight Test Facility, Dallas Fort Worth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATSA-SURF</td>
<td>Under development</td>
<td>UPS fleet currently use SafeRoute. Sensis datalink technology equipped in a wide variety of aircraft across Europe.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Taxi and Ramp Management and Control Airborne System (TARMAC-AS)</td>
<td>Under development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electronic Taxiway Navigation Array (ETNA)</td>
<td>Deployed</td>
<td>Frankfurt International Airport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Runway incursion technology enablers
7.4. OPERATIONAL CONCEPTS IN THE SESAR PERSPECTIVE

7.4.1. The SESAR Context

The SESAR ATM Target Concept is classified into Lines of Changes (LoC), which describe the main areas which need to be further enhanced to reach the implementation of the SESAR ATM Target Concept. The specific and detailed changes required to transition from today's system have been structured in a series of Operational Improvement (OI) Steps, defined along the LoCs. A detailed transition path from today onwards has been developed [16].

The OI Steps have been allocated to one of the three Implementation Packages (IPs), depending upon their start of operation:

- IP1 from 2008 – up to 2013 – “Creating the Foundations” by building on the current ongoing European ATM initiatives contributing to capacity improvements which are building the basis for and leading to the ATM Target Concept;
- IP2 from 2013 – up to 2020 – “Accelerating ATM to Implement the 2020 ATM Target Concept”, by timely implementation of all the activities needed to achieve the 2020 targets;
- IP3 from 2020 – onwards – “Achieving the SESAR goals in the long-term”, targeting the activities necessary for further performance enhancement of the overall ATM System beyond 2020 to fully realise the ATM Target Concept.

7.4.2. Airport surface safety nets and SESAR Operational Improvements (OIs)

The following table shows the OI steps that are planned within Airport Safety Nets for Pilot and Controllers operational project [17]. Shaded rows represent OIs not described in the Roadmap. Each OI short description and corresponding Key Performance Area (KPA) where benefits are expected is given. In addition, the OI steps are mapped to proposed operational concepts in Section 5 explaining what OIs proposed solutions deliver (Table 6) [18].
### OI Step

<table>
<thead>
<tr>
<th>OI Step reference</th>
<th>OI step description</th>
<th>Timeframe (IOC-FOC)</th>
<th>IP</th>
<th>KPA</th>
<th>Operational concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO-0103</td>
<td>Improved Runway-Taxiway Lay-out, Signage and Markings to Prevent Runway Incursions</td>
<td>2009-2016 1</td>
<td>Safety Efficiency 1, 2</td>
<td>Mobile 1, 2 Both 1, 2</td>
<td></td>
</tr>
<tr>
<td>AO-0102</td>
<td>Automated Alerting of Controller in Case of Runway Incursion or Intrusion into Restricted Areas</td>
<td>2008-2015 1</td>
<td>Safety Security 1, 2, 3</td>
<td>ATCO 1, 2, 3</td>
<td></td>
</tr>
<tr>
<td>CM-0807</td>
<td>Enhanced Ground-based Safety Nets Using Wide Information Sharing</td>
<td>2017-2020 2</td>
<td>Safety Interoperability 1, 2, 3</td>
<td>Mobile 1, 2, 3 Both 1, 2, 3</td>
<td></td>
</tr>
<tr>
<td>AUO-0605</td>
<td>Automated Alerting of Runway Incursion to Pilots (and Controller)</td>
<td>2013-2018 2</td>
<td>Safety 1, 2</td>
<td>Both 1, 2</td>
<td></td>
</tr>
<tr>
<td>OI Step</td>
<td>OI step reference</td>
<td>OI step description</td>
<td>Timeframe (IOC-FOC)</td>
<td>IP</td>
<td>KPA</td>
</tr>
<tr>
<td>---------</td>
<td>------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td>Airport Safety Nets including Taxiway and Apron</td>
<td>AO-0104</td>
<td>The systems detect potential conflicts/incursions involving mobiles (and stationary traffic) on runways, taxiways and in the apron/stand/gate area. The alarms are provided to controllers, pilots, and vehicle drivers together with potential resolution advisories (depending on the complexity of resolution possibilities). The systems also alert the controller in case of unauthorized / unidentified traffic.</td>
<td>2013-2018</td>
<td>2</td>
<td>Safety</td>
</tr>
<tr>
<td>Airport Vehicle Driver's Traffic Situational Awareness</td>
<td>AO-0204</td>
<td>Information regarding the surrounding traffic (incl. Both aircraft and airport vehicles) during taxi and runway operations is displayed in the vehicle driver's cockpit.</td>
<td>2013-2017</td>
<td>2</td>
<td>Safety</td>
</tr>
<tr>
<td>Enhanced Trajectory Management through Flight Deck Automation Systems</td>
<td>AUO-0604</td>
<td>Use of advanced aircraft automated systems such as e.g. auto-brake (making it impossible for an aircraft to cross a lit stop bar) and auto-taxi (optimising speed adjustment).</td>
<td>2018-2023</td>
<td>2</td>
<td>Safety Environment Efficiency</td>
</tr>
<tr>
<td>Enhanced Vision for the Pilot in Low Visibility Conditions</td>
<td>AUO-0403</td>
<td>Out the window positional awareness is improved through the application of visual enhancement technologies thereby reducing the difficulties of transition from instrument to visual flight operations.</td>
<td>2013-2018</td>
<td>2</td>
<td>Safety</td>
</tr>
</tbody>
</table>

Table 6: SESAR OI Steps and Operational Concepts
8. OPERATIONAL SCENARIOS

8.1. CATEGORY 1: NON-CONFORMANCE TO ATC INSTRUCTIONS/PROCEDURES

The Category 1 is presented by three operational scenarios. These are:

- Mobile B not stopping at the holding point of taxiway B;
- Mobile A not following the clear taxiway route; and
- Mobile’s non-conformance to ATC procedures includes.

8.1.1. Scenario 1: Mobile B is not stopping at the holding point

Description: Mobile B was issued a clearance to stop at the holding point of taxiway B. This clearance assumes that Mobile B will taxi onto taxiway B and stop at the holding point. However, in this scenario Mobile B deviates from the ATC clearance, crosses the holding point of taxiway B and rolls towards the active runway (i.e. aircraft is cleared to land or to take-off) (Figure 14). The reasons behind the deviation may include, but are not limited to:

- Pilot error;
- Disorientation of pilot. The pilot is on the wrong taxiway believing to be on taxiway b. This lack of situational awareness makes a potential resolution of this event more difficult;
- Miscommunications between controllers and flight crews or vehicle drivers (e.g. readback/hearback error); or
- Misunderstanding of the ATC clearance between controllers and flight crews or vehicle drivers. Note that difference with disorientation is marginal: the pilot knows exactly where he is, without realising deviation from the route foreseen by the controller.

Sequence of events:

- Mobile B is issued with a clearance to stop at the holding point of taxiway B; and
- Mobile B is detected as crossing the holding point by the A-SMGCS;
- Mobile B is approaching an active runway.
- The safety net alert can be given to:
  o Cockpit/cabin of Mobile B (either as visual or auditory alert) to stop rolling towards the active runway;
  o Cockpit/cabin of Mobile on the active runway (either as visual or auditory alert) to stop rolling, abort the take-off or initiate the go-around manoeuvre (in case of landing);
  o The controller (as visual A-SMGCS level 2 alert). This would require an additional resolution time as the controller requires time to make and execute his/her decision (immediately contact one or both mobiles);
  o All parties involved. This option requires a great deal of care to avoid any ambiguity that may exist between the alert issued to Mobiles and the one issued to the controller.

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Operational issues:

- Constraints: The system needs to detect aircraft not stopping on the holding point.

This particular scenario represents also the following situations:

- Mobile B is not stopping at the red stopbar whilst another Aircraft is taking off from runway;
- Mobile B is not stopping at the red stopbar whilst another Aircraft is landing at runway; and
- Aircraft B is lined up for take off or landing on already active runway A

8.1.2. Scenario 2: Deviation from a cleared taxiway route

Description: Mobile A was issued a clearance to taxi on a clear route from taxiway A to taxiway D (Figure 15). However, in this scenario Mobile A deviates from the ATC clearance by turning onto taxiway B (e.g. potentially occupied). The reasons behind the deviation may include, but are not limited to:

- Pilot error;
- Disorientation of pilot. The pilot/driver of mobile A will turn onto taxiway B thinking he is on taxiway D. This lack of situational awareness will make a potential resolution of this event more difficult;
- Miscommunications between controllers and mobile a (readback/hearback error); or
- Misunderstanding of the ATC clearance between controllers and mobile a. Note that difference with disorientation is marginal: the pilot will know that he is located on taxiway B, without realising that he is supposed to be on taxiway D (not realising a deviation from the route foreseen by the controller).

Sequence of events:

- Mobile A is issued with a clearance to taxi from TWY A to TWY D; and
- Mobile A is detected as turning onto TWY B.
- The safety net alert can be given to:
  - Cockpit/cabin of Mobile A (either as visual or auditory alert) to stop taxiing towards taxiway B;
  - Cockpit/cabin of Mobile on the taxiway B (either as visual or auditory alert) to immediately stop;
The controller (either as visual or auditory alert). This would require an additional resolution time as the controller requires time to make and execute his/her decision (immediately contact the mobile involved);

- All parties involved. This option requires a great deal of care to avoid any ambiguity that may exist between the alert issued to Mobile(s) and the one issued to the controller.

Figure 15: Deviation from a clear route on a taxiway

This particular scenario represents also the following situations:

- Mobile A is deviated to taxiway B that is inappropriate/unsuitable with regards to the aircraft type, i.e. taxiway is too narrow; and
- Mobile A is cleared to use taxiway B that is inappropriate/unsuitable with regards to the aircraft type.

8.1.3. Scenario 3: Non-conformance to ATC procedures

Non-conformance to ATC procedures includes, but is not limited to the following scenarios:

- Excessive taxi speed;
- Aircraft close to runway without landing clearance; and
- Taking off without the clearance.

8.1.3.1. Scenario 3.1: Excessive taxi speed

**Description:** Mobile A is manoeuvring with excessive speed on the movement area (compared to other traffic). This may induce unexpected situations at taxiway intersections (priority not given or not respected). The reasons behind the non-conformance with the taxiway speed restriction may include, but are not limited to:

- Pilot error;
- Miscommunications between controllers and mobile a (readback/hearback error); or
- Misunderstanding of the ATC clearance between controllers and mobile A.

**Sequence of events:**
• Mobile A is issued with a clearance to taxi on TWY A;
• Mobile A is not respecting taxiway speed limit;
• Excessive taxiway speed limit is detected by the system;
• The safety net alert can be given to:
  o Cockpit/cabin of Mobile A (either as visual or auditory alert) to reduce its speed;
  o The controller (either as visual or auditory alert) that taxiing speed is exceeded;
  o All parties involved.

Figure 16: Excessive taxi speed

Operational issues:

• Publication of taxi speed limits: currently defined by airliners for their respective fleet.
• Nuisance alerts: if there is no traffic at the next taxiway intersection.

8.1.3.2. Scenario 3.2: Aircraft close to runway without landing clearance

Description: Aircraft A is in the vicinity of runway A without the clearance to land. The reasons behind this may include, but are not limited to:

• Pilot error (assuming the landing clearance);
• Controller error (not issuing the landing clearance);
• Miscommunications between controllers and Aircraft A (readback/hearback error); or
• Misunderstanding of the ATC clearance between controllers and Aircraft A.

Sequence of events:

• Aircraft A is cleared on final approach to runway A;
• Aircraft A is not cleared to land on runway A;
• The safety net alert can be given to:
  o Cockpit/cabin of Aircraft A (either as visual or auditory alert);
  o The controller (either as visual or auditory alert);
  o All parties involved.
8.1.3.3. Scenario 3.3: Taking off without the clearance

**Description:** Aircraft A is taking off from runway A without the clearance. The reasons behind this may include, but are not limited to:

- Pilot error (assuming the take off clearance);
- Controller error (not issuing the take off clearance);
- Miscommunications between controllers and mobile a (readback/hearback error); or
- Misunderstanding of the ATC clearance between controllers and Aircraft A.

**Sequence of events:**

- Aircraft A is cleared to line up on runway A;
- Aircraft A is not cleared to take off from runway A;
- The safety net alert can be given to:
  - Cockpit/cabin of Aircraft A (either as visual or auditory alert);
  - The controller (either as visual or auditory alert);
  - All parties involved.
### CATEGORY 1: NON-CONFORMANCE TO ATC INSTRUCTIONS/PROCEDURES

<table>
<thead>
<tr>
<th>Alert issued to</th>
<th>Alert Level</th>
<th>Alert issued is</th>
<th>Alert type: V-visual, A-auditory, B-both</th>
<th>Safety net system available</th>
<th>Technological enablers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATCO</td>
<td>1: INFORMATION</td>
<td>NA</td>
<td>V-visual, A-auditory, B-both</td>
<td>NA</td>
<td>A-SMGCS &amp; EFS</td>
</tr>
<tr>
<td></td>
<td>2: ALARM</td>
<td>Runway incursion</td>
<td>V-visual, A-auditory, B-both</td>
<td>A-SMGCS Level 1&amp;2 RIMCAS</td>
<td>A-SMGCS &amp; EFS ITWP</td>
</tr>
<tr>
<td>Mobile</td>
<td>1: INFORMATION</td>
<td>NA</td>
<td>V-visual, A-auditory, B-both</td>
<td>NA</td>
<td>A-SMGCS &amp; AGL</td>
</tr>
<tr>
<td></td>
<td>2: ALARM</td>
<td>Runway incursion</td>
<td>V-visual, A-auditory, B-both</td>
<td>None</td>
<td>A-SMGCS &amp; AGL SURV: SMRS, MLAT, COMM: R/T and datalink, EFS, D-TAXI (possibly a CAATS system), Controller tools, Integrated Tower Working Position (ITWP)</td>
</tr>
<tr>
<td>All</td>
<td>1: INFORMATION</td>
<td>as above</td>
<td>V-visual, A-auditory, B-both</td>
<td>NA</td>
<td>A-SMGCS Level 1&amp;2 RIMCAS as above</td>
</tr>
<tr>
<td></td>
<td>2: ALARM</td>
<td>as above</td>
<td>V-visual, A-auditory, B-both</td>
<td>A-SMGCS Level 1&amp;2 RIMCAS</td>
<td>as above Sum of all above</td>
</tr>
</tbody>
</table>

#### Scenario 2: Deviation from a cleared taxiway route

<table>
<thead>
<tr>
<th>ATCO</th>
<th>1: INFORMATION</th>
<th>Aircraft on wrong taxiway</th>
<th>NA</th>
<th>A-SMGCS &amp; EFS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2: ALARM</td>
<td>Collision^2</td>
<td>A-SMGCS Level 1&amp;2 RIMCAS</td>
<td>A-SMGCS &amp; EFS</td>
</tr>
</tbody>
</table>

^2 In case of occupied taxiway.
## Operational concept & requirements for airport surface safety nets

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1: INFORMATION</th>
<th>2: ALARM</th>
<th>Sum of all above</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile</td>
<td>Wrong taxiway</td>
<td>None</td>
<td>Surface Movement Guidance System</td>
</tr>
<tr>
<td></td>
<td>Collision</td>
<td>None</td>
<td>Surface Movement Guidance System</td>
</tr>
<tr>
<td>All</td>
<td>as above</td>
<td>as above</td>
<td>Sum of all above</td>
</tr>
</tbody>
</table>

### Scenario 3: Non-conformance to ATC procedures (example of excessive taxi speed)

<table>
<thead>
<tr>
<th></th>
<th>1: INFORMATION</th>
<th>2: ALARM</th>
<th>Sum of all above</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATCO</td>
<td>Speed limit exceeded</td>
<td>None</td>
<td>ATCO Tool</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>Mobile</td>
<td>Speed limit exceeded</td>
<td>None</td>
<td>Surface Movement Guidance System</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>All</td>
<td>as above</td>
<td>as above</td>
<td>Sum of all above</td>
</tr>
<tr>
<td></td>
<td>as above</td>
<td>as above</td>
<td></td>
</tr>
</tbody>
</table>
8.2. CATEGORY 2: CONFLICTING ATC CLEARANCES

This category covers scenarios which include conflicting ATC clearances involving two runway movements, such as:

- Both Aircraft A and Aircraft B are issued a clearance to land,
- Both Aircraft A and Aircraft B issued a clearance to take off,
- One aircraft is issued a clearance to take off whilst the other is issued a clearance to land,
- One aircraft is issued a clearance to land whilst the other is issued a clearance to cross/enter runway,
- One aircraft is issued a clearance to take off whilst the other is issued a clearance to cross/enter runway.

8.2.1. Scenario 1: Conflicting clearances (two aircraft involved)

Description: Aircraft A is cleared for landing on final approach to runway A. Aircraft B is cleared to take off from runway B. These two ATC clearances are conflicting, unsafe, and may result in an accident (Figure 19). The reasons behind the issuance of conflicting clearances may be the operational error by controller(s) involved.

Sequence of events:

- Aircraft A is cleared for final approach on runway A;
- Aircraft B is cleared to take off from runway B (i.e. two conflicting clearances have been issued by the controller);
- The safety net alert can be given to:
  - Aircraft A (either as visual or auditory alert) to abort landing and initiate a go around manoeuvre;
  - Aircraft B to abort the take-off;
  - The controller (as visual A-SMGCS level 2 alert). This would require an additional resolution time, as the controller requires time to make and execute his/her decision (immediately contact both aircraft);
- All parties involved. This option requires a great deal of care to avoid any ambiguity that may exist between the alert issued to Aircraft A and B and the one issued to the controller.
### CATEGORY 2: CONFLICTING ATC CLEARANCES

<table>
<thead>
<tr>
<th>Alert issued to</th>
<th>Alert Level</th>
<th>Alert issued is</th>
<th>Alert type: V-visual, A-auditory, B-both</th>
<th>Safety net system available</th>
<th>Technological enablers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Currently</td>
<td>In future</td>
<td></td>
</tr>
<tr>
<td><strong>ATCO</strong></td>
<td>1: INFORMATION</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>
|                 | 2: ALARM    | Runway incursion | A-SMGCS Level 2 | A-SMGCS & EFS | • SURV: PSR, SSR, SMR, MLAT  
• COMM: R/T and datalink  
• EFS  
• D-TAXI (possibly a CAATS system)  
• Controller tools  
• Integrated Tower Working Position (ITWP) |
| **Aircraft**    | 1: INFORMATION | NA              | TCAS      | A-SMGCS & AGL | • SURV: PSR, SSR, SMR, MLAT  
• COMM: R/T and datalink  
• D-TAXI (possibly a CAATS system)  
• Stopbars  
• Aerodrome ground lights  
• Ground vehicle transponders  
• Surface Movement Guidance System  
• Electronic Flight Bag |
|                 | 2: ALARM    | Runway incursion | TCAS      | A-SMGCS & AGL | On-board Runway Conflict Alerting |
| **All**         | 1: INFORMATION | as above        | as above  | as above  | Sum of all above |
|                 | 2: ALARM    | as above        | as above  | as above  | Sum of all above |
8.3. CATEGORY 3: INFRINGEMENTS

There are two types of events that constitute Category 3 operational scenarios. These are:

- Infringement of closed runway; and
- Infringement of restricted/closed taxiways (or areas).

Note: All scenarios in this category can be easily placed within the Categories 1 or 2. The reason why they are combined in a separate infringement category is to differentiate operational scenarios which have reference to the airport layout.

8.3.1. Scenario 1: Infringement of closed runway

Description: Aircraft A is on final approach to runway A (Figure 20). Runway A is closed for maintenance. The reasons behind this infringement may include, but are not limited to:

- Controller error;
- Pilot error;
- Disorientation of the pilot in aircraft A. The pilot of aircraft A will initiate a visual approach to runway A thinking it is some other runway. This lack of situational awareness will make a potential resolution of this event more difficult; or
- Miscommunications between controllers and aircraft A (readback/hearback error).

Note: The alert level depends on the aircraft intent.

In the case of aircraft taking off:

- Level 1 is foreseen to inform Aircraft A if it is taxiing on the closed runway (Caution: Runway closed) and controller (Aircraft on closed runway);
- Level 2 is foreseen to inform Aircraft A if it is rolling for take-off (Runway closed) and controller (Take-off on closed runway).

In the case of aircraft landing:

- Level 1 is foreseen to inform Aircraft A (“Caution: Runway closed!”) and controller (Aircraft on final approach to closed runway);
- Level 2 is foreseen when any Mobile rolls on the runway, information is given both to Mobile (Runway closed) and controller (Landing on closed runway).

Sequence of events in the case of landing aircraft:

- Aircraft A is detected as landing on the closed runway A (Figure 17);
- The safety net alert can be given to:
  - Aircraft A (either as visual or auditory alert) to abort landing and head to the alternative runway;
The controller (either as visual or auditory alert). This would require an additional resolution time as the controller requires time to make and execute his/her decision and immediately contact Aircraft A;

All parties involved. Any ambiguity that may exist between the alerts issued to Aircraft A and the controller need to be eliminated.

Sequence of events in the case of aircraft taking off:

- Aircraft A is detected on the closed runway A (Figure 18);
- The safety net alert can be given:
  - As Level 1 to Aircraft A (either as visual or auditory alert) to stop taxying on the closed runway A;
  - As Level 1 to the controller (either as visual or auditory alert) that Aircraft A is on the closed runway;
  - As Level 2 to Aircraft A (either as visual or auditory alert) to abort take off from the closed runway A;
  - As Level 2 to the controller (either as visual or auditory alert) that Aircraft A is taking off from the closed runway;
  - All parties involved. Any ambiguity that may exist between the alerts issued to Aircraft A and the controller need to be eliminated.
Operational issues:

- Rate of false/nuisance alerts: due to incorrect detection of aircraft movements (turns);
- Determine the threshold between the triggering of Level 1 and Level 2 alarm;
- Constraints: The system needs to exclude all maintenance vehicles (working on the closed runway) from the constant Levels 1 and 2 alerts.

This particular scenario represents also the following situations:

- Any mobile crossing the closed runway; and
- Mobile A is cleared to take-off or land on RWY A that is inappropriate/unsuitable with regards to the aircraft type (i.e. RWY is too short).

8.3.2. Scenario 2: Infringement of restricted/closed taxiways (areas)

Description: Mobile A is cleared to taxiway D. Mobile A deviates from the ATC clearance and proceeds onto closed/restricted taxiway B. The reasons behind the resulting infringement of the closed/restricted taxiway may include, but are not limited to:

- Pilot error;
- Disorientation of the pilot in aircraft A. The pilot of aircraft a will initiate final approach to runway A thinking it is some other runway. This lack of situational awareness will make a potential resolution of this event more difficult; or
- Miscommunications between controllers and aircraft a (readback/hearback error); or
- Misunderstanding of the ATC clearance between controllers and flight crews or vehicle drivers. Note that difference with disorientation is marginal: the pilot will know that he is located on taxiway B, without realising it is closed.

Sequence of events:

- Mobile A is cleared to taxiway D (Figure 19);
- Mobile A taxis to the closed taxiway B;
- The safety net alert can be given:
  - As Level 1 to the controller (either as visual or auditory alert) that Mobile A is on the closed taxiway. In this case, the controller will immediately contact the driver/pilot of Mobile A to clear the closed taxiway B; and
  - As Level 2 to Mobile A (either as visual or auditory alert) that it is on the closed taxiway in close proximity to another Mobile or ground personnel (maintenance workers).
**Figure 22: Infringement of restricted/closed taxiway**

**Note:** The alert level depends on the type of restricted areas. Therefore:

- Level 1 is given to the controller (e.g. “Restricted/closed area/taxiway infringement”);
- Level 2 is given to Mobile A when aircraft movement may threaten ground personnel (maintenance work).

**Operational issues:**

- Constraints: How will the system know which taxiway is restricted/closed? A constraint identified is system information on closed taxiways and that is possible today, taxiways can be blocked on the A-SMGCS HMI. Therefore, this should not be considered as a constraint for tower systems. It could still be a constraint for safety nets that are provided to the cockpit.
<table>
<thead>
<tr>
<th>Alert issued to</th>
<th>Alert Level</th>
<th>Alert issued is</th>
<th>Alert type: V-visual, A-auditory, B-both</th>
<th>Safety net system available</th>
<th>Technological enablers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Currently</td>
<td>In future</td>
<td></td>
</tr>
<tr>
<td>Example 1: Infringement of closed runway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATCO</td>
<td>1: INFORMATION</td>
<td>Caution: Closed runway</td>
<td>None</td>
<td>A-SMGCS &amp; EFS</td>
<td>• SURV: PSR, SSR, SMR, MLAT</td>
</tr>
<tr>
<td>Mobile</td>
<td>2: ALARM</td>
<td>Aircraft is approaching or taking off from the closed runway</td>
<td>None</td>
<td>A-SMGCS &amp; EFS</td>
<td>• COMM: R/T and datalink</td>
</tr>
<tr>
<td>Mobile</td>
<td>1: INFORMATION</td>
<td>Caution: Closed runway</td>
<td>None</td>
<td>A-SMGCS &amp; AGL</td>
<td>• D-TAXI (possibly a CAATS system)</td>
</tr>
<tr>
<td>Mobile</td>
<td>2: ALARM</td>
<td>Approaching closed runway</td>
<td>None</td>
<td>A-SMGCS &amp; AGL</td>
<td>• EFS</td>
</tr>
<tr>
<td>All</td>
<td>1: INFORMATION</td>
<td>as above</td>
<td>as above</td>
<td>as above</td>
<td>Sum of all above</td>
</tr>
<tr>
<td>All</td>
<td>2: ALARM</td>
<td>as above</td>
<td>as above</td>
<td>as above</td>
<td></td>
</tr>
<tr>
<td>Example 2: Infringement of closed/restricted taxiway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATCO</td>
<td>1: INFORMATION</td>
<td>Closed taxiway</td>
<td>None</td>
<td>A-SMGCS &amp; EFS</td>
<td>• SURV: SMR, MLAT</td>
</tr>
</tbody>
</table>

3 This is cleared for later stages of the integrated A-SMGCS and AGL system
<table>
<thead>
<tr>
<th>Mobile</th>
<th>2: ALARM</th>
<th>Aircraft is on the closed taxiway</th>
<th>None</th>
<th>A-SMGCS &amp; EFS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1: INFORMATION</td>
<td>NA</td>
<td>None</td>
<td>Surface Movement Guidance System</td>
</tr>
<tr>
<td></td>
<td>2: ALARM</td>
<td>Closed taxiway</td>
<td>None</td>
<td>Surface Movement Guidance System</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• SURV: SMR, MLAT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• COMM: R/T and datalink</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• D-TAXI (possibly a CAATS system)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Ground vehicle transponders</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>• GPS</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• ADS-B Tier 2 service + CDTI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Surface Movement Guidance System</td>
</tr>
<tr>
<td>All</td>
<td>1: INFORMATION</td>
<td>as above</td>
<td>as above</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td>2: ALARM</td>
<td>as above</td>
<td>as above</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sum of all above</td>
</tr>
</tbody>
</table>
9. OPEN ISSUES

The following operational and technical issues associated to the proposed new safety nets for surface movement operations have been identified:

- A common concern is the level of the potential false and nuisance alerts raised by safety net applications and this represents the main criteria for their acceptance by ATCOs or flight crews;

- The draft ConOps and Roadmap document present the current picture of several technical enablers that are under development. Since the timeframe for the full airport surface safety nets implementation (2007 – 2013) covers the development period of these technical enablers, it is necessary to revisit and update their status on a regular basis.

In addition following issues need to be addressed:

- Requirement for identification of preferred concept option (note: can vary locally, also in relation to equipage levels of typical traffic);

- Priority setting in conflicts to be addressed, possibly in relation to maturity of technology and ability of different technologies to address certain conflicts (e.g. focussing airfield lighting systems on protecting runway areas);

- Dependency on aircraft equipage in terms of navigation and surveillance (how does equipage develop over time in terms of functionality):
  - Ability to determine own position in relation to environment (requirement on equipage of own aircraft only);
  - Ability to determine position of other aircraft in relation to other aircraft (requirement on equipage of own aircraft and possibly on other aircraft, unless traffic information is provided through ATC function);
  - Ability to analyse traffic information and provide alert if required.

- Legal issues should be addressed in the future and there may be a need for investigation during the validation process whether any aspects of the concept will affect the responsibilities of pilots or controllers.

Further development of typical operational scenarios may be considered at later stage to address features such as:

- Detection of taxiway conflicts (e.g. aircraft approaching intersections with converging traffic) and apron conflicts: currently the potential false or nuisance alerts rate is deemed high by the operational experts consulted.

- Monitoring of a prescribed longitudinal spacing between aircraft (currently, there is no minimum distance separation defined for surface movements).