EUROPEAN AIRPORT MOVEMENT MANAGEMENT BY A-SMGCS

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EMMA Air-Ground Operational Service and Environmental Description (OSED-update)

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Table of Contents

1 Introduction

1.1 Scope of the Document

The OSED Update (D1. 3.1u) document covers the specification of the operational services related to A-SMGCS from the perspective of ATC Controllers (ATCOs), Flight Crews and Vehicle Drivers and in the context of European airports operations.

The description of the services is completed by the identification of the expected benefits, the anticipated constraints, and the associated human factors.

The operational services have been analysed against operational procedures (existing and new ones proposed) as well as considerations of equipment on the ground and on-board. A series of initial proposals for implementation package has been identified.

In addition the document contains the description of the current airport operational environment in Europe, taking as an example the 4 airports that host EMMA tests.

The structure of the document is organised as follows:

- Section 2: Description of EMMA services to ATCOs, Flight Crews and Vehicle Drivers
- Section 3: Steps for EMMA Services
- Section 4: Expected Benefits, Anticipated Constraints and Associated Human Factors
- Section 5: Initial EMMA Proposals for A-SMGCS Implementation Packages
- Section 6: Operational Environment

1.2 Relationships to other EMMA Documents

The OSED Update Document is the reference document, from which the Operational Requirements Document (ORD) and Technical Requirement Documents (TRD and AGFA) have been derived.

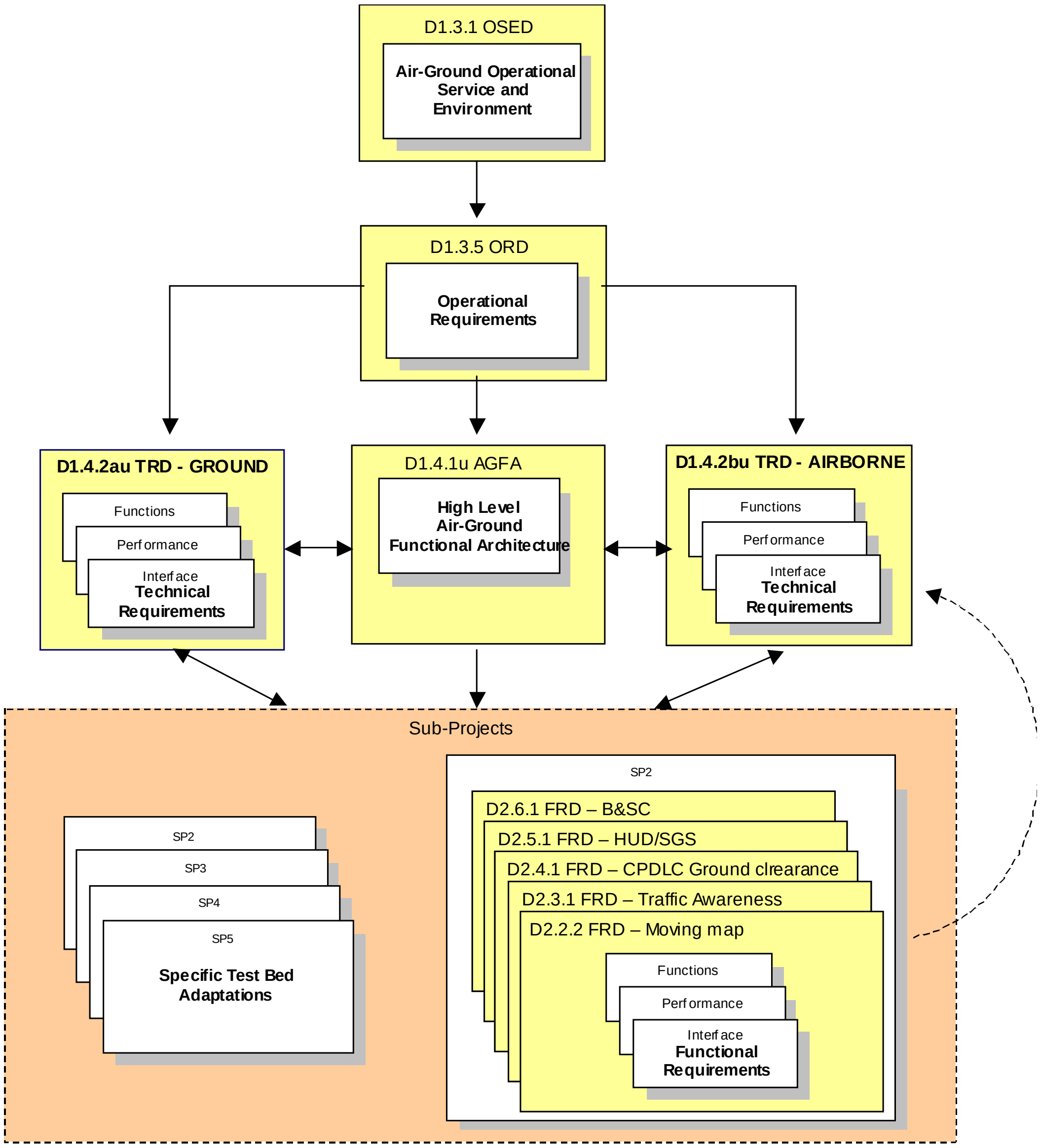


Figure 1-1: Relationships between EMMA SP1 documents

1.3 Guidance for usage

This section describes how the EMMA OSED is related to other EMMA documents, the ICAO Manual (doc 9830) and to the Eurocontrol APR A-SMGCS project.

The ICAO Manual is guidance material for A-SMGCS that is accepted worldwide. It is the achievement of a discussion over years and the EMMA OSED refers to this regulatory document. However, EMMA is an R&D project thus aims to provide constructive critics and recommendations to this ICAO manual. Critics and recommendations base on profound investigation results, that themselves found on service descriptions outlines by this document.

Furthermore, this EMMA OSED documents bases on the Eurocontrol APR A-SMGCS documents however goes beyond Eurocontrol work by outlining A-SMGCS services of higher implementation levels. Nevertheless, basic Eurocontrol documents are fully inline with the ICAO Manual. They are valid Europe-wide. Eurocontrol is further detailing the ICAO Manual to provide practical implementation guidance material for Europe. The scope of the EUROCONTROL work is a proper subset of the scope of the ICAO Manual reflecting practical constraints & realities. For a more detailed disquisition see the EMMA working paper "Impact of ICAO Manual and EUROCONTROL Documents to EMMA" [26] that results on an agreement between the EMMA OSED authors, the EMMA project leader DLR, the European Commission and representatives of the Eurocontrol APR A-SMGCS project.

This working paper also addresses how ICAO, EUROCONTROL, and EMMA deal with the A-SMGCS levels of implementation:

(1) *The term "level" is used at ICAO and EUROCONTROL with a slightly different meaning, which led to some confusion.*

ICAO Levels are "one means of grouping A-SMGCS implementation" ("an example"). The purpose is to recommend certain groupings for certain aerodrome layouts, traffic densities and visibility conditions.

EUROCONTROL Levels are more related to the practical implementation sequence. They are driven by urgency of operational need, the dependencies of services, enablers, equipment and cost – and the ICAO level definition criteria. The purpose is to "form a coherent series" to enable the evolutionary implementation.

Further on, this working paper outlines the guidelines how the OSED and all other EMMA documents have to behave to present ICAO and Eurocontrol documents:

(2) *The following options have been considered for EMMA documents:*

- *Follow EUROCONTROL <u>and</u> ICAO documents – for the subset where EMMA as an 'Implementation and Policy Support Project' is dealing with the already performed EUROCONTROL work*
- *Follow ICAO documents where EMMA as an R&D project goes beyond the EUROCONTROL A-SMGCS work*
- *Deviate from the ICAO document because there are very good reasons for that, which have to be explained in detail*

Taking into account this regulatory frame following action plan has been applied to produce this document:

<u>Phase 1</u>

In a first step, the OSED started to present each SERVICE, in a stepwise approach in terms of complexity and/or level of implementation that could correspond to a pragmatic implementation of the services (in term of operational needs for instance).

This services description did contain a description of all function for each service independent on former definitions of implementation levels.

<u>Phase 2</u>

In a second step, **equipment** considerations has been taken into account by means of a table enumerating items of equipment that could be involved for an implementation of aforementioned services at a given step of complexity.

Industrial partners' valuable input has been used in this phase to define degrees of complexity, implementation wise, of the identified services.

<u>Transition phase</u>

Results of phase 2 have been forward to the authors of the EMMA Operational Requirements Document D135 [21] who generated "**draft procedures**" that described role and responsibility of each EMMA users/actors.

<u>Phase 3</u>

Finally, the EMMA OSED proposes a matrix that presents the EMMA proposed implementation packages. This matrix bases on ICAO but is improved according to what ICAO does not address today: **Equipment** and **procedures.**

1.4 EMMA Overview

As outlined by the EUROCONTROL ATM2000+ Strategy as well as the ACARE SRA work, airports represent the future bottlenecks of air transport and development of '...enhanced operational concepts, supported by new decision-making or decision-support tools to ensure more efficient use of the airport infrastructure...' is a key challenge for air transport.

The A-SMGCS project 'EMMA'[2] delivers the European consolidated R&D contribution to these goals by maturing and validating the A-SMGCS operational concept as an integrated air-ground system, seamlessly embedded within the overall ATM system. EMMA project takes place between 2004 and 2008.

1.4.1 Main principles

A-SMGCS provides ATC controllers, flight crews and vehicle drivers several services aiming at supplementing visual observation for traffic situational awareness (surveillance service), at raising awareness of potential safety hazardous situations and supporting ATC control actions (control service), at devising taxi routing information for the efficient use of airport resource and to cope with planning constraints set for other phases of the flight (routing service) as well as at providing guidance for taxi movements of aircraft and vehicles (guidance service)

In order to deliver the optimal benefits for the efficiency of aircraft movements, A-SMGCS must be coherently inter-linked and interact with other adjacent units and authorities.

Considering the ICAO A-SMGCS Manual and building on the A-SMGCS Levels I and II defined by Eurocontrol Airport Operations Programme, EMMA has focused on the specification of new operational services and their supporting enablers, i.e. human actors, operational procedures, equipment and technical standards, for the planning of surface movements or using onboard equipment that will be available within a 15 year horizon.

1.4.2 Assumptions

In the course of the EMMA project, several assumptions with respect to the availability of potential operational services within a 15 year timeframe have been made and summarised below:

- No changes to the current respective roles and responsibilities of ATC Controllers, Flight Crews and Vehicle Drivers for airport operations is anticipated;
- The provision of 'electronic vision' to Flight Crews is covered by EMMA services but not to the point where the 'see and avoid' principle is applicable in low visibility conditions (when flight crews can not avoid each other using visual information);

[2] EMMA is a two-phase project. The first phase is called just EMMA, the second phase is called EMMA 2. In this document 'EMMA' means always the first two years phase of the overall EMMA project.

1.4.3 Stakeholders

The OSED document takes into account the perspective and viewpoints of the following stakeholders:

- **Airlines**

The airlines are the main stakeholder with respect to operational improvements for the safety and efficiency of surface movements. The OSED document consolidates the view from airlines with respect to operational services and their related benefits.

- **Air Navigation Service Providers (ANSP) and ATC Controllers (ATCOs)**

European ANSPs are the providers of ATC services through the implementation of operational procedures and required ground equipments. The OSED document consolidates their view with respect to operational services and the proposed implementation packages depending on key factors such as airport layout, traffic density, number of low visibility days.

- **Airport Operator**

Airport Operators are users of A-SMGCS for the provision of apron service (sometimes delegated to ATC) and the use of EMMA routing function results for accurate in-block time estimation or required off-block time adjustment.

- **Ground Handlers and Vehicle Drivers**

Ground Handlers and Vehicle drivers are users of A-SMGCS services for safe and efficient movements of airport vehicles.

- **Aeronautics Industry**

Aeronautics Industry is part of the EMMA project to support the definition and validation of A-SMGCS operational services and the proposed implementation packages.

1.5 Explanation of terms

Note:

This section provides an explanation of the terms required for a correct understanding of this document.

ICAO A-SMGCS definitions [1] are used as a first option. In general, other definitions are only used where it is necessary to have a more precise technical definition than the ICAO definition. In such cases, it is explained why another definition is preferred to the ICAO definition. When there is no ICAO definition, definition comes from the EUROCAE MASPS for A-SMGCS [24] , or from Eurocontrol documents [7]. In that case, it is indicated in the definition.

Advanced Surface Movement Guidance and Control Systems (A-SMGCS) [ICAO-A-SMGCS]

Systems providing routing, guidance, surveillance and control to aircraft and affected vehicles in order to maintain movement rates under all local weather conditions within the Aerodrome Visibility Operational Level (AVOL) whilst maintaining the required level of safety.

Aerodrome [ICAO-Annex14] [ICAO-A-SMGCS]

A defined area on land or water (including any buildings, installations, and equipment intended to be used either wholly or in part for arrival, departure, and surface movement of aircraft.

Aerodrome Visibility Operational Level (AVOL) [ICAO-A-SMGCS]

The minimum visibility at or above which the declared movement rate can be sustained

Airport authority [ICAO-A-SMGCS]

The entity responsible for the operational management of the airport

Alert [ICAO-A-SMGCS]

An indication of an existing or pending situation during aerodrome operations, or an indication of abnormal A-SMGCS operation, that requires attention and/or action

Alert Situation [EUROCAE-MASPS]

Any situation relating to aerodrome operations, which has been defined as requiring particular attention or action

Apron [ICAO-Annex14] [ICAO-A-SMGCS]

A defined area on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance

A-SMGCS capacity [ICAO-A-SMGCS]

The maximum number of simultaneous movements of aircraft and vehicles that the system can safely support wit an acceptable delay commensurate with the runway and taxiway capacity at a particular aerodrome

Conflict [ICAO-A-SMGCS]

A situation when there is a risk for collision between aircraft and/or vehicles

Control

[EUROCAE-MASPS]

Application of measures to prevent collisions, runway incursions and to ensure safe, expeditious and efficient movement

Cooperative aircraft / vehicle [EUROCAE-MASPS]

Aircraft / vehicle, which is equipped with systems capable of automatically, and continuously providing information including its Identity to the A-SMGCS

Note: "Target" has been replaced by "aircraft / vehicle" in "Cooperative target" [EUROCAE-MASPS] definition.

Note: as several cooperative surveillance technologies exist, an aircraft or a vehicle is cooperative on an aerodrome only if the aircraft / vehicle and the aerodrome are equipped with cooperative surveillance technologies, which are interoperable.

Cooperative surveillance

The surveillance of aircraft / vehicles is cooperative when a sensor, named cooperative surveillance sensor, collects information about the aircraft / vehicles from an active element of the transponder type, which equips the aircraft / vehicles. This technique allows collecting more aircraft / vehicle parameters than the non-cooperative surveillance, for instance the aircraft / vehicles identity.

Data Fusion [EUROCAE-MASPS]

A generic term used to describe the process of combining surveillance information from two or more sensor systems or sources

False Alert [EUROCAE-MASPS]

Alert, which does not correspond to an actual alert situation

Note: It is important to understand that it refers only to false alerts and does not address nuisance alerts (i.e. alerts which are correctly generated according to the rule set but are inappropriate to the desired outcome).

Guidance

[EUROCAE-MASPS]

Facilities, information and advice necessary to provide continuous, unambiguous and reliable information to pilots of aircraft and drivers of vehicles to keep their aircraft or vehicles on the surfaces and assigned routes intended for their use

Identification [ICAO-A-SMGCS]

The correlation of a known aerodrome movement call sign with the displayed target of that aircraft / vehicle on the display of the surveillance system

Identity [ICAO-4444]

A group of letters, figures or a combination thereof which is either identical to, or the coded equivalent of, the aircraft / vehicle call sign to be used in air-ground communications, and which is used to identify the aircraft / vehicle in ground-ground air traffic services communications

Note: "Aircraft identification" [ICAO-4444] definition has been extended to vehicles.

Incursion [ICAO-A-SMGCS]

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, take-off, taxiing, and parking of aircraft.

Intruder

???

Any aircraft / vehicle, which is detected in a specific airport area into which it is not allowed to enter.

Low Visibility

Refers to Visibility Conditions 3 and 4, see Visibility Condition

Manoeuvring area [ICAO-Annex14] [ICAO-A-SMGCS]

That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons

Modularity [ICAO-A-SMGCS]

Capability of a system to be enhanced by the addition of one or more modules to improve its technical or functional performance

Movement

The movement of an aircraft / vehicle on the airport movement area.

Movement area [ICAO-Annex14] [ICAO-4444] [ICAO-A-SMGCS]

That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and apron(s)

Non-Cooperative aircraft / vehicle [EUROCAE-MASPS]

Aircraft / vehicle, which is not equipped with systems capable of automatically, and continuously providing information including its Identity to the A-SMGCS

Note: In the definition, "target" has been replaced by "aircraft / vehicle."

Non-Cooperative surveillance

The surveillance of aircraft / vehicles is non-cooperative when a sensor, named non-cooperative surveillance sensor, detects the aircraft / vehicles, without any action on their behalf. This technique allows determining the position of any aircraft / vehicle in the surveillance area and in particular to detect intruders. Examples of non-cooperative surveillance sensors are the Primary Surveillance Radars

Nuisance Alert [EUROCAE-MASPS]

Alert, which is correctly generated according to the rule, set but are inappropriate to the desired outcome

Obstacle [ICAO-Annex14] [ICAO-A-SMGCS]

All fixed (whether temporary or permanent) and mobile obstacles, or parts thereof, that are located on an area intended for the surface movement of aircraft / vehicles or that extend above a defined surface intended to protect aircraft in flight

Note 1: The term fixed obstacle designates the elements such as antennas, building, ground lights…that present a risk for aircraft during landing, take-off or surface movements, especially for aircraft parts such as wingtips and tail, which are out of sight of the flight crew

Note 2: In the context of EMMA the following option is investigated: the A-SMGCS should detect any new obstacles (i.e. not previously recorded in an aeronautical database), whether moving or stationary, located anywhere on the movement area of the aerodrome and having an equivalent radar *cross section of 1 sq. m or more.*

Note 3: As specified in ICAO Doc 9137 Airport Service Manual, the responsibility for the control of fixed obstacles is assumed by the Aerodrome Operator.

Protection area

A protection area is a virtual volume around a runway, a restricted area or an aircraft or a vehicle. This protection area is used to detect an alert situation. For instance, an alert situation is detected when a aircraft / vehicle is on a runway and one or more aircraft / vehicles enter the runway protection area

Restricted Area

Aerodrome area where the presence of an aircraft or a vehicle is permanently or temporarily forbidden

Route [ICAO-A-SMGCS]

A track from a defined start point to a defined endpoint on the movement area

Routing [EUROCAE-MASPS]

The assignment of a route to individual aircraft and vehicles to provide safe, expeditious, and efficient movement on the aerodrome movement area. Such route consists in a track from a defined starting point to a defined end point on the movement area

Runway Incursion [ICAO-A-SMGCS]

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

Stand [ICAO-A-SMGCS]

A stand is a designated area on an apron intended to be used for the parking of an aircraft

Surveillance [ICAO-A-SMGCS]

A function of the system, which provides identification and accurate positional information on aircraft, vehicles and obstacles within the required area

Target [ICAO-A-SMGCS]

An aircraft, vehicle, or obstacle, that is displayed on a surveillance display.

Note: This definition (this definition has been preferred to the [EUROCAE-MASPS] definition).

Note: The term "Target" will only be used when considering an image of n aircraft or a vehicle or an obstacle displayed on a surveillance screen.

Visibility Conditions [ICAO-A-SMGCS]

4 Visibility Conditions are defined as follows in Appendix A of the ICAO A-SMGCS Manual:

Visibility Condition 1

Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, and for personnel of control units to exercise control over all traffic on the basis of visual surveillance.

Visibility Condition 2

Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance.

Visibility Condition 3

Visibility sufficient for the pilot to taxi but insufficient for the pilot to avoid collision with other traffic on taxiways and at intersections by visual reference, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. For taxiing this is normally taken as visibilities equivalent to a RVR of less than 400 m but more than 75 m.

Visibility Condition 4

Visibility insufficient for the pilot to taxi by visual guidance only. This is normally taken as a RVR of 75 m or less.

2 EMMA Services Description

The section identifies the various operational services that form the A-SMGCS at 2015 time horizon taking into account the different users (ATCOs, flight crew, vehicle drivers)

This description remains independent of A-SMGCS levels as defined by ICAO or Eurocontrol.

2.1 Services to ATC Controllers (ATCO)

2.1.1 Surveillance

The A-SMGCS surveillance service should ensure that controllers receive all necessary information on all aircraft and vehicles on the movement area (including their identification) down to the AVOL (§3.1a [1]).

The ATCO will be assisted by a surveillance service, consisting of the presentation of Traffic Situation for the Controller, unaffected by operationally significant effects such as adverse weather - see 6.1.3 in this document - and topographical conditions[3]. The ATCO completes its visual observation by watching on the A-SMGCS surveillance display:

- Identification of, at least, all cooperative aircraft in the movement area
- Detection and accurate position of all aircraft in the movement area;
- Identification of all cooperative vehicles in the movement area;
- Detection and accurate position of all vehicles in the movement area;
- Detection and accurate position[4] of all obstacles in the movement area;
- The airport traffic context (Airport layout, including runways, taxiways and apron area, runway status, time, weather and operational configuration - see 6.1.2.2 in this document -);

Since ATC is responsible for the manoeuvring area, the surveillance service should cover all movements on this area, including obstacle-free zones and protected areas. In case ATC controllers are responsible for the aircraft movements in the apron area, surveillance service should also cover both aircraft and vehicles in those areas where manoeuvring aircraft may come into conflict with each other or with vehicles. All participating movements, aircraft and vehicles[5], are expected to be cooperative, so the surveillance service will automatically provide their identity on the ATCO display.

However, it could also be possible for the ATCO to cope with a VERY limited number of non-cooperative movements (grass cutting vehicles, aircraft with transponder out of service or not equipped). These non-cooperative movements may not be automatically labelled. Thus, a non-cooperative sensor system will be necessary in order to detect these vehicles as well as potential intruders.

The surveillance service shall support the operations in all visibility condition, mainly when ATCOs have no visual contact to surface movements.

Functions included in the Surveillance Service for ATCO are:

- Provide Traffic Information: including detection, position, and identification of movements.
- Provide Traffic Context: including airport layout, operational configuration, time, weather, and runway status.

[3] Topographical conditions are whatever (non restricted to) shaded areas due to mountains, obstacles or any other object.
[4] Throughout the document, the word *detection* will be used not only to define *detection* but *accurate position* as well, understanding that those concepts are different: *detection* defines to discover or ascertain the existence of an object and *accurate position* represents to determine the co-ordinates, speed and heading of the object.
[5] At least all vehicles moving on the manoeuvring area should be co-operative. What vehicles have to be equipped on the remaining parts of an airport (apron) depends on many local circumstances and has to be decided from airport to airport.

- Interface to the ATCO: providing surveillance information to the ATCO and supporting the ATCO´s interaction with the surveillance display.

A-SMGCS surveillance service provides information that serves as the basis for the rest of A-SMGCS services. To illustrate this, some examples of the relation between Surveillance and Control services are displayed below:

1. Detect deviations from the assigned route[6]

   The routing function (see 2.1.3 in this manual) supports the ATCO to generate a taxi route primary by different levels of automation. When the route is in the A-SMGCS the surveillance system should be capable of detect deviations comparing the theoretical position its real position.

2. Detect any incursion into protected areas

   The control function (see 2.1.2 in this manual) supports the ATCO to detect any incursions into protected areas. This information provided by the control function is an input in the surveillance function.

3. Predict and resolve conflicts

   The control function (see 2.1.2 in this manual) supports the ATCO to predict and resolve conflicts. This information provided by the control function is an input in the surveillance function.

The surveillance service will also provide the information required by the Guidance Service (through the guidance function – see 2.1.4 in this manual), to provide guidance to surface movements and to enable all pilots and drivers to maintain situational awareness of their position on the assigned routes.

2.1.1.1 Provide Traffic Information

This function is in charge of providing the traffic information. The system should provide accurate position of all movements within the movement area. It also should provide the detection and identification of movements corresponding to co-operative movements. Surveillance should also be provided for aircraft on approach to each runway in airside.

The traffic information can be collected from different systems: cooperative / non-cooperative surveillance sensor systems, approach surveillance systems and other systems (i.e. ATC system and Airport Authority systems)

From the analysis of the requirements stated in ICAO doc 9830, it can be concluded that:

- a non-cooperative surveillance system is needed to detect any movement on the surface, in the movement area, in particular intruders;
- a cooperative surveillance system is needed to provide the identity of the participating movements on the surface, in the movement area;
- an approach surveillance system will provide the information on departing / arriving aircraft in airside and, in general, all airborne aircraft (also potential intruders) in the TMA and above a threshold altitude (e.g. 100 ft.);

All the traffic information provided by these different sources need to be computed in order to obtain a consistent traffic information picture. This is performed by the "Data Fusion" function.

All the above sub-functions are described as follows:

- **Data input of traffic information from non-cooperative surveillance sensor systems:**

At least one non-cooperative surveillance sensor system is needed to detect any movement on the

[6] The importance of heading information is noted, especially for routing (depending on the heading of parked aircraft different taxi routes have to be assigned).

surface, in particular intruders. This system (e.g. SMR) is able to provide the position of any movement on the airport surface within the movement area if the direct line between SMR and movement is not impaired by other traffic, other fixed obstacle/buildings or by an insufficient radar angle. Frequently, more than one SMR (or other additional non-cooperative sensor systems) are needed to get full coverage.

- **Data input of traffic information from cooperative surveillance sensor systems:**

The system should be able to provide the detection and identification of the cooperative movements. At least one cooperative surveillance system (e.g. ADS-B / Mode S) is needed to provide the identity of the participating cooperative movements on the surface. All the participating movements are required to be co-operative, allowing the cooperative surveillance sensor system to collect information about the movements, at least their identity.

- **Data input of traffic information from approach RDPS:**

Surveillance should be provided for aircraft on approach to each runway at such a distance that inbound aircraft can be integrated into A-SMGCS operations so that aerodrome movements, including aircraft departures or aircraft crossing active runways, can be managed. The approach RDPS (Radar Data Processing System) will provide the information (at least position and identity) on airborne aircraft to be covered by A-SMGCS. In the future, this surveillance data could be collected from different sensor systems such as Automatic Dependant Surveillance.

- **Data input of other information about traffic:**

Other systems will provide any other traffic information (e.g. aircraft type, gate...) which may be required by local authority. Also, the coordination of surveillance information between Airport and Approach Centre should be clearly targeted. That means, there should be a correlation between the information provided by the Approach Centre and the information received by the Airport, and vice versa.

- **Data Fusion:**

The surveillance information provided by the different surveillance sensor systems is combined by a data fusion process to provide a comprehensive surveillance package. The system should be capable of updating the surveillance information needed for the guidance and control requirements both in time and position along the route.

2.1.1.2 Provide traffic context

This function is in charge of providing the traffic context: It includes airport layout (runways, taxiways, and apron area), airport operational configuration, runways status, time, and meteorological information. The traffic context data may be automatically obtained from other systems (MET systems, ATC systems and Airport Authority systems), or introduced into the system by a human operator. It means this function is composed of the following sub-functions:

- **Acquisition of traffic context from other ground systems:**

This function is in charge of automatically providing the traffic context obtained from other systems (MET systems, ATC system and Airport Authority systems).

- **Manual update of traffic context:**

This function is in charge of providing the traffic context (airport configuration e.g. runways in use, taxiways available, runways status,) introduced into the system by a human operator.

-

The traffic context provided by the different sources (automatic or manual) could be combined to provide a comprehensive traffic context package.

2.1.1.3 Interface with user

This function is in charge of providing to the users all the surveillance data required generated by the service monitoring process, demonstrating an acceptable level of HMI efficiency.

The HMI should save the Controller some time and make him aware of situations that he could not have taken into account without this assistance. It must, of course, be interactive to enable the controller to make it evolve and find the information he needs in time.

2.1.1.4 Quality of service Aspects

It should be guaranteed that the function will be implemented only in a stage, where false signals appear in a much reduced percentage that fulfils current ICAO requirements.

The surveillance functions should be capable of detecting aircraft, vehicles, and obstacles. Methods should be employed to reduce adverse effects such as signal reflections and shadowing to a minimum §4.2.1 [1].

A reference point of an aircraft and vehicles is required to enable the A-SMGCS to determine their position §4.2.2 [1].

The actual position of an aircraft vehicle or obstacle on the surface should be determined within a radius of 7.5 m. Where airborne traffic participates in the A-SMGCS, the level of an aircraft when airborne should be determined to within ± 10m. §4.2.3 [1].

The position and identification data of aircraft and vehicles should be updated at least once per second §4.2.4 [1].

The latency and validation of surveillance position data for aircraft and vehicles should not exceed 1 second. The latency and validation of identification data for aircraft and vehicles should not exceed 3 seconds §4.2.5 [1].

2.1.2 Control

ICAO defines control as the "application of measures to prevent collisions, runway incursions and to ensure safe, expeditious, and efficient movement". Within A-SMGCS, the control function is understood as the assistance provided by the system to support airport tactical operations as well as to provide guidance in planning execution and undertaking ad-hoc decisions.

The control function of an A-SMGCS should (§2.5.4.1 [1]):

a) have a capacity sufficient for the maximum authorized movement rate (dynamic capacity);

b) have a capacity sufficient for the aerodrome planning of requested movements for a period of up to one hour (static capacity);

c) be able to provide longitudinal spacing to predetermined values of;
1) speeds;
2) relative directions;
3) aircraft dimensions;
4) jet blast effects;
5) human and system response times; and
6) deceleration performances.

d) be capable of incorporating computer-aided management tools;

e) keep controllers, pilots and vehicle drivers in the decision loop;

f) control movements within a speed range such as to cover the operations in all required situations, taking into account the type of movement;

g) be capable of allowing operations to continue in all visibility conditions down to AVOL; and

h) be capable of allocating priorities to control activities.

With these considerations the control function should be able of (§2.5.4.1 [1]):

a) detect conflicts and provide resolutions;

b) provide alerts for incursions to runways and activate protection devices (e.g. stop bars or alarms);

c) provide alerts for incursions to taxiways and activate protection devices (e.g. stop bars or alarms);

d) provide alerts for incursions to critical and sensitive areas established for radio navigation aids;

e) provide alerts for incursions to emergency areas;

The current control function is to be improved by the A-SMGCS by implementing incursion alerts and tools to predict, to detect, and to resolve conflicts.

Furthermore, the control function is also to include automated support to ATC Clearances and ATCO transfer co-ordination between ground / tower and approach / tower.

Consequently, the main sub-functions included in a control function in an A-SMGCS are:

- Detection and alerting function
- Support to ATC clearance and coordination function
- Conflict resolution function

2.1.2.1 Detection and alerting function

The detection and alerting function gives assistance to air traffic controllers in their control tasks by:

- Anticipating conflicts: this could be done for the short or for the medium term when:
  - a restricted area[7] / runway / taxiway incursion is predicted to take place (runway/taxiway/restricted area incursions caused by aircraft or vehicles),
  - the computed route deviation will be more than a preset / predefined maximum deviation,
  - the predicted spacing between movements is below preset / predefined minima, or
  - any conflict concerning any movement on the movement area.
- Detecting already existing conflicts as the ones detailed in the previous bullet points.
- Additionally, this function should be able of activating protection devices such as e.g. stop bars or alarms.

It should be noted that false alarms should be reduced to provide air traffic controllers with the necessary confidence in such automated support. Consequently, in order to reduce the false alarms, a control service may first only detect easiest or most dangerous alarm situations, and progressively be completed with other alarm situations when they are well understood.

Depending on the level of implementation, the EMMA control service should:

- Primarily contribute to operations as a safety net, preventing hazards resulting from flight crew or vehicle driver deviations or from operational errors or deviations.
- Transmit alerts to concerned mobiles.
- Improve decision support of ATCOs by providing conflict resolution advisory (e.g. immediately vacate runway for a vehicle)

In this regard, the implementation of the detection and alerting function depends very much on the definition of the conflict cases as well as their associated operational procedures or working methods to solve each of them as there are factors intrinsic to each airport: runways system, taxiways system and apron and access to it. Therefore a specific tuning of the function for its implementation is required depending on the airport.

To enable ATC to carry out the control of both aircraft and vehicles on the manoeuvering area, an A-SMGCS should be designed to at least assist in the prevention of (§3.2.2.9 [1]):

- incursions of aircraft and vehicles onto runways and taxiways in all visibility conditions; and
- collisions between:
  1. aircraft operating on the manoeuvering area in all visibility conditions;
  2. aircraft and vehicles operating on the manoeuvering area in all visibility conditions;
  3. aircraft operating on the manoeuvering area and obstructions on that area in all visibility conditions;
  4. vehicles operating on the manoeuvering area in visibility condition 3[8] and 4[9]; and
  5. vehicles operating on the manoeuvering area and obstructions on that area in visibility condition 4 (in visibility condition 3 for vehicles and obstructions is not necessary)

[7] Such as e.g. critical and sensitive areas established for radio navigation aids or emergency areas.
[8] As stated by the ICAO's A-SMGCS Manual Appendix A, visibility condition 3 implies visibility sufficient for the pilot to taxi but insufficient for the pilot to avoid collision with other traffic on taxiways and at intersections by visual reference, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. For taxiing, this is normally taken as visibilities equivalent to an RVR of less than 400 m. but more than 75 m.
[9] As stated by the ICAO's A-SMGCS Manual Appendix A, visibility condition 4 implies visibility insufficient for the pilot to taxi by visual guidance only. This is normally taken as an RVR of 75 m. or less.

In the event that ATC assumes the control service on the aerodrome aprons, an A-SMGCS should be designed to at least assist in the prevention of (§3.2.2.10 [1]):

- incursions of aircraft and vehicles onto designated areas and routes in all visibility conditions; and
- collisions in visibility conditions 3 and 4 between:
    1. aircraft;
    2. aircraft and vehicles
    3. aircraft and obstructions;
    4. controlled vehicles; and
    5. controlled vehicles and obstructions.

Every aerodrome has site-specific parameters and situations to be addressed. As stated by the ICAO's Advanced Surface Movement Guidance and Control Services (A-SMGCS) Manual (§3.4.5.7 [1]), the following list provides some of the possible conflict alert scenarios that should be both predictable and detectable[10] by the A-SMGCS. Vehicle movements should also be considered in all the alert scenarios.

The following list enumerates the conflicts that are considered in EMMA. The list is identical to ICAO doc. 9830, with the small difference that "arriving aircraft exiting runway at high speed with converging taxiway traffic" is considered within EMMA as a taxiway conflict instead of a runway conflict.

- runway conflicts
    1. aircraft arriving to, or departing on, a closed runway;
    2. arriving or departing aircraft with traffic on the runway (including aircraft beyond the runway-holding positions);
    3. arriving or departing aircraft with moving traffic to or on a converging or intersecting runway;
    4. arriving or departing aircraft with opposite direction arrival to the runway;
    5. arriving or departing aircraft with traffic crossing the runway;
    6. arriving or departing aircraft with taxiing traffic approaching the runway (predicted to cross the runway-holding position);
    7. arriving aircraft with traffic in sensitive area (when protected);
    8. aircraft exiting the runway at unintended[11] or non-approved[12] locations;
    9. unauthorized traffic approaching the runway; and
    10. unidentified traffic approaching the runway;

- taxiway conflicts
    1. arriving aircraft exiting runway at high speed with converging taxiway traffic;[13]
    2. aircraft on a closed taxiway;
    3. aircraft approaching stationary traffic;
    4. aircraft overtaking same direction traffic;
    5. aircraft with opposite direction traffic;
    6. aircraft approaching taxiway intersections with converging traffic;
    7. aircraft taxiing with excessive speed;
    8. aircraft exiting the taxiway at unintended or non-approved locations;
    9. unauthorized traffic on the taxiways;
    10. unidentified traffic on the taxiways; and
    11. crossing of a lit stop bar; and

- apron / stand / gate conflicts:

[10] A detected conflict, which requires immediate action to prevent a collision, should be given priority over a predicted conflict, which requires expeditious action to avoid the development of an imminent situation. The alerting system should indicate this difference by providing a different set of alerts to the users of the system.
[11] An unintended locations is any runway exit location different from that the ATCO authorized
[12] An non-approved locations is any runway exit location non authorized by the ATCO.
[13] In ICAO doc 9830 this item is considered as a Runway Conflict.

1. aircraft movement with conflicting traffic;
2. aircraft movement with conflicting stationary objects;
3. aircraft exiting the apron / stand / gate area at unintended or non-approved locations;
4. unidentified traffic in the apron / stand / gate area.

Additionally, another possible conflict alert scenario should consider the event when computed deviations are more that the preset/predefined maximum deviations.

While it is agreed, as stated by the ICAO Advanced Surface Movement Guidance and Control Systems (A-SMGCS) §3.4.5.10 [1] manual, that a robust system should process all aircraft and vehicles at an acceptable rate, priorities should be established so as to ensure that system logic performs efficiently. The runway represents the area with the highest risk of a catastrophic event. Therefore, the detection and prediction of conflicts in this area should be addressed first. Conflict alerting priorities should be as follows:

1. runway conflicts;
2. taxiway conflicts;
3. and apron / stand / gate conflicts.

As stated by the ICAO A-SMGCS Manual §3.2.1.3 [1], the controller concerned will have primary responsibility to operate and interpret the information coming from the A-SMGCS. Pilots and vehicle drivers will be responsible to respond to an A-SMGCS instruction or alert, unless specifically instructed otherwise by the controller. However, conflict detection is an example of a responsibility which may be delegated in some circumstances to an automated system §3.2.1.4 [1].

2.1.2.2 Support to ATCO Clearance and Coordination

Currently ATC Controllers issue clearances for surface movements using voice communication and in some cases data-link services (such as departure clearance DCL). The automated support with respect of clearances is of two types:

- information about cleared movements, time constraints for flights together with surveillance information, this requires controller's manual input
- support for the use of CPDLC for controller-pilot dialogs for non-time-critical clearances such as departure clearance, start-up, push-back, and taxi clearance

The conditions for transfer of control of aircraft between approach and tower controllers and for aircraft and vehicles between ground and tower controllers are predefined and published in the AIP and in letters of agreement between adjacent ATC Centres (see explanations in section 6.3.3). Silent handover is the most common practice in European airports.

To support such process, the system should complement the surveillance information with information on what movements have been cleared by the adjacent ATCOs (e.g. aircraft cleared for lining-up on the runway is known by the Ground Controller).

With the introduction of automation of surface movement planning and air-ground data links, the support to ATCO coordination should also cover the acceptance process of taxi routing decisions between Ground and Tower Controllers and the notification of the Flight Crews at the appropriate time.

Automated clearance will support and could be an aid to the transfer co-ordination between both of the next:

- Ground and tower control and
- Approach and tower control.

This data-link service allows pilots to request - and controllers to give - start-up, push-back and taxi clearances via data link. It is expected to reduce the voice channel congestion currently experienced at many major airports. In addition, it is likely to enhance safety by reducing the risk of misunderstandings caused by regional accents and radio signal quality between pilots and controllers

The system automatically generates departure clearances in response to request from towers and flight services stations; it could forward the clearance without controller involvement. Clearance elements are formed with consideration of adapted data and current environmental conditions such as aircraft type, weight category, runway configuration, preferred departure, and other routes.

The system will provide assistance in entering restrictions, instructions, and holds. There will be two possible ways to give a clearance to an aircraft:

a) ATCO introduces the clearance into the system.
b) The system proposes a clearance automatically that can be accepted, modified or changed by the ATCO.

2.1.2.3 Conflict resolution function

The A-SMGCS should provide the air traffic controller with a solution to the conflict detected. Following along the lines of the previous function, the implementation of the conflict resolution function depends very much on the definition of the conflict cases as well as their associated operational procedures to solve them.

Once detected or predicted, a conflict should be resolved according to its severity. There should be sufficient time to resolve a predicted conflict through the planning process. However, an actual conflict requires immediate action, which may be a system- or human-initiated resolution.

In the event of distinctive medium term conflicts, the A-SMGCS should be able to predict the conflict, to detect it and finally to resolve it. In any case, once a conflict has been detected, the A-SMGCS should either automatically resolve the conflict or, on request from the controller, provide the most suitable solution. In this regard, two types of messages to the ATCO should be considered: medium-term information that represents a potentially hazardous situation but which does not require immediate action, and short-term alarms requiring immediate action.

The conflict alerting and resolution flow diagram is shown in Figure 2-1.

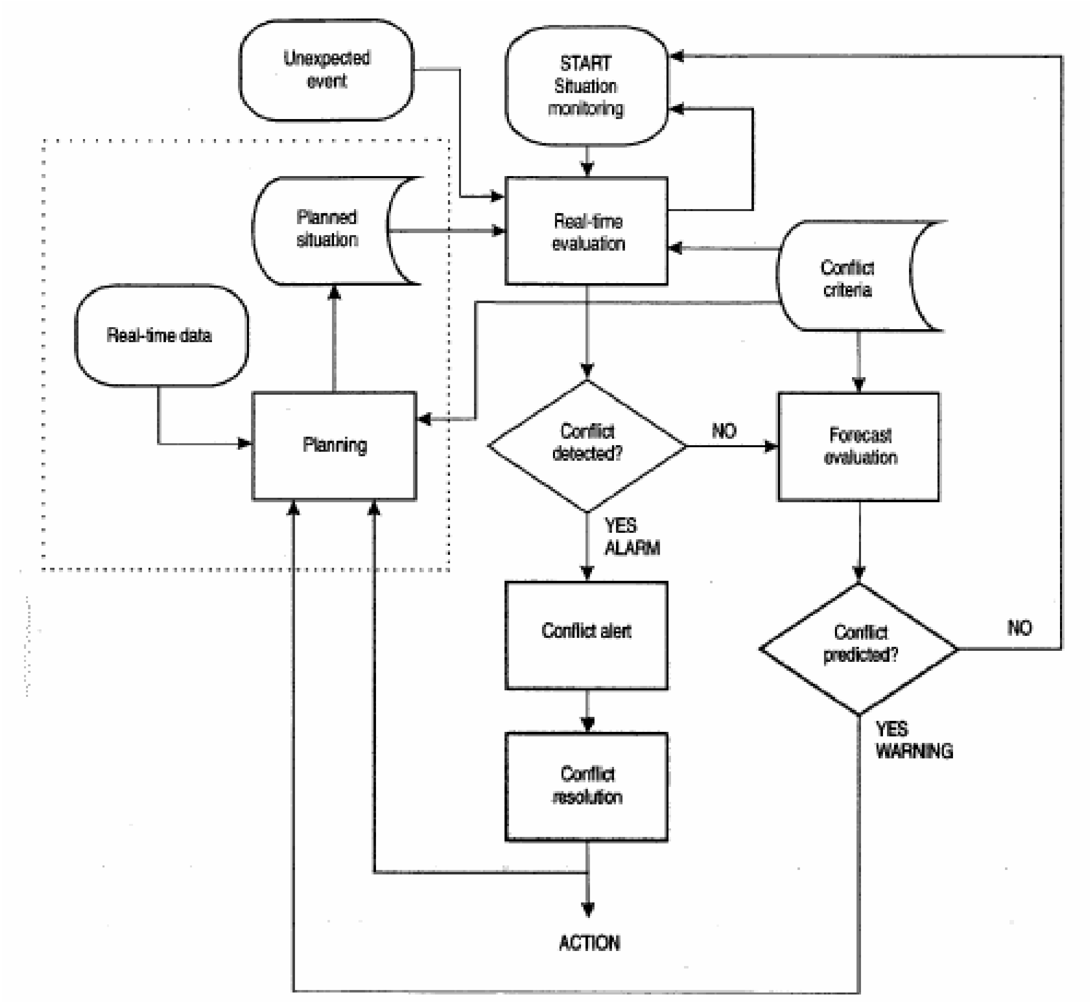


Figure 2-1: Conflict alerting and resolution flow diagram (ICAO A-SMGCS Manual §3.4.5.6 [1])

When the conflict is detected by the system it will be displayed at the air traffic controller HMI which issues an alarm to the controller. Consequently, the controller will stop the taxiing of the aircraft involved and / or issue alternative clearances to eventually prevent any hazard. It has to be taken into account that aircraft on final approach must have a higher priority than any other aircraft on the ground. In the same way, aircraft at take-off are to be prioritized in order to keep a safe take-off process and to maintain the runway throughput.

2.1.2.4 Quality of service Aspects

- A reference point of an aircraft and vehicles is required to enable the A-SMGCS to determine their position §4.2.2 [1].
- The probability of detection of an alert (PDA) situation should be greater than 99.9 per cent (§4.5.1 [1]).
- The probability of false alert (PFA) should be less than 0.1 per cent (§4.5.1 [1]).
- The response time of any control function should be less than 0.5 second (§4.5.2 [1]).
- Longitudinal spacing should be according with the numerical values indicated by ICAO (§4.5.3 [1]).

2.1.3 Routing

Note: As only ATCOs are responsible to provide routing for all authorised movements on the aerodrome, a routing service is dedicated to the ATCO exclusively. There is no direct routing service provided to flight crew or vehicle drivers. Nevertheless, the pilot or vehicle driver can request a taxi route from the ATCO.

It must be distinguished between

a) Generation and assignment of a route, which is <u>routing</u> and

b) Transmission of a route to the flight crew or to vehicle drivers, which is part of a control service and guidance service, but <u>not routing</u>. The taxi route is transmitted to the aircraft or vehicles either by R/T voice communication or/and by an upload data link. Route requests via data link are part of an onboard service.

Routing, as well as Surveillance, Guidance, and Control, are seen as a **primary functions** within an A-SMGCS (§2.2.1 [1]). By ICAO [1] a route describes "*A track from a defined starting point to a defined end point on the movement area*". However, *"In order to achieve the maximum benefits at each level of A-SMGCS implementation, a supporting planning function should be included" (§2.2.2 [1]).*

That is, a planning function, as defined by ICAO, is seen as a **supporting function** to all other primary functions, but not only associated with routing. However, since planning is mainly associated with routing services and also to avoid inconsistencies and confusion with other sections of this document, the service of an A-SMGCS planning function is described within this section.

The EUROCAE [24] WG-41 group acts with a similar definition but integrates routing and planning to one Route/Planning function: *"A function of A-SMGCS which provides strategic and tactical allocation of routes and times to aircraft and / or vehicles to provide safe, expeditious and efficient movement from the current position to the intended position"*.

By EMMA (in accordance to ICAO) the routing function is seen as a primary A-SMGCS function that supports the ATCO to generate a taxi route primary. This route generation can be performed by different levels of automation. Further on, the more the generation and assignment of a taxi route is automated the more support of a planning function and other information have to be considered to guarantee safe and most efficient routes (see also §1.3.5 and 1.3.12 [1].

<u>Levels of automation of the routing function</u>

With ICAO, the criteria whether a routing function is automated or not is the *assignment* of a route to an aircraft or vehicle (compare §2.5.2 [1]).

(1) If the assignment of a route is done by the control authority, routing is <u>manual</u>.

(2) When the routing function gives additional advisory information to the ATCO to assign a route, ICAO speaks of a <u>semi-automatic</u> routing function (§2.5.2.2 [1]).

(3) When further on the route is a) assigned automatically and b) provides adequate information to enable manual intervention in the event of a failure or at the discretion of the control authority, then ICAO means that routing is fully <u>automated</u> (§2.5.2.3 [1]).

This allocation of routing levels in terms of automation is adopted by EMMA.

2.1.3.1 Manual Routing

Generally, ICAO requires that a routing function should (§2.5.2.1 [1]):

a) Be able to designate a route for each aircraft or vehicle within the movement area;

c) Allow for a change of destination at any time;

d) Allow for a change of route;

e) Be capable of meeting the needs of dense traffic at complex aerodromes; and

f) Not constrain the pilot's choice of a runway exit following the landing.

With manual routing, the service shall allow the ATCO to input a route into the A-SMGCS and to assign it to an aircraft or a vehicle (including towing).

The **route input** could be performed, but is not restricted to:

- Via the A-SMGCS surveillance display by selecting a target with the mouse cursor and signing the route by clicking on topographical waypoints (topological nodes) until the final position is reached or/and
- Alphanumerically input via keyboard or touch screen direct into the electronic flight stripes (EFS), or/and
- Via speech recognition

The manual routing function should also able to compute a **valid taxi route** between a given start and end point taking into account local standard routes.

The destination or the complete route can be changed at every time by any authorised controller.

As the manual input of a route is supposed to be very time consuming particularly with dense traffic, this task should be performed by a separate planning or assistant controller who is not involved in active control.

Another mitigation means (if no separate assistant controller is available) to avoid too much additional work for the executive controller would be to use manual routing only with low visibility conditions when "route deviation alerts" could be used as an additional safety net[14].

2.1.3.2 Semi-automatic Routing

A *manual* routing service moves forward to a *semi-automatic* routing service through provision of additional advisory information to the control authority when generating and assigning a route (see §2.5.2.2 [1]). Such advisory information is hardly described up to now, so that different advisory information is conceivable. Basically, main information that an ATCO needs to assign a proper taxi route are as follows:

- Position and identification of the concerned movement
- Intended position (destination)
- Constraints (standard routes, type of a/c, heading, priorities, time constraints, blocked taxiways, visibility conditions, etc.)

Most of this information is provided by the traditional out-the-window view, radio telephony (position reports, inspection cars), surveillance displays (SMR or A-SMGCS), and flight plan data processing system.

Depending on the kind of ATM operational environment, the routing function should have access to such external information, process it, and provide proper route advisory information to the control authority.

Advisory information of semi-automatic routing should indicate the probable **most suitable taxi route** that includes the **shortest taxi distance** and **current constraints** that are known to the function. Therefore the routing function must have access to the flight plan data processing system to get information about the:

a) Start point (Stand/Gate, runway exit)

[14] For more explanation to "route deviation alert" see "Control Service to ATCO".

b) The runway exit can be predicted by the aircraft wake vortex category, which information is in the flight plan, or more reliable by an interface to the A-SMGCS surveillance function.

c) End point (Stand/Gate, assigned runway entry point)

d) In order to refine the prediction of the most suitable route, additional information/constraints should take into account by the routing function:

e) Local standard routes

f) Local taxi restrictions with LVP (e.g. limitations for taxiways)

g) Type of aircraft (some heavy aircraft may be restricted for some taxiway)

h) Closed taxiways

i) Restricted areas

j) Obstacles

k) Temporary hazards

l) Intermediate waypoints (e.g. de-icing, temporary parking positions)

m) Time constraints (e.g. blocked taxiways, runways that are known in advance)

The information to operate with standard routes, announcement of LVP, closed taxiways, restricted areas, obstacles, temporary hazards, de-icing, or temporary parking positions requirements, has to be input manually to the routing function if there is no interface to the A-SMGCS surveillance or control function.

If the ATCO object to the computed taxi route because of additional information/constraints that are not known to the routing function, the ATCO can easily select an alternative route (see also §3.5.13.8 [1]). If no suitable route proposal is available, the ATCO has to generate a route by manual means (cf. 2.1.3.1).

2.1.3.3 Automatic Routing

Automatic routing is given when the computed route is assigned by the routing function (§2.5.2.3, [1]).

> Note: To put a route into action (in terms of giving clearances to pilots and vehicle drivers) remains a control task and is still under responsibility of the ATCO.

However, the *automatic assignment* should not be the only criterion; further more it should be guaranteed that the assignment of a taxi route is reasonable and reliable to meet best all current constraints and to prevent the ATCO of too many manual interventions. Therefore, the routing function needs every information the ATCO usually needs to generate a taxi route.

Automatic routing is particularly indicated at complex aerodromes when traffic density is heavy. (§3.4.2.1 [1])

When routes are assigned automatically, ICAO requires further on (§2.5.2.4 [1]):

a) Minimise taxi distance in accordance with the most efficient operational configuration

b) Be interactive with the control function to minimise crossing conflict

c) Be responsive to operational changes (e.g. runway changes, routes closed for maintenance, and temporary hazards or obstacles)

d) Use standardized terminology or symbology

e) Be capable of providing routes as and when required by all authorised users; and

f) Provide a means of validating routes

To fulfil these requirements the routing function needs access to all external resources that determine a taxi route. Supplementary, to be *most efficient*, a **planning function** has to be implemented.

Planning activities are categorised by different time horizons. ICAO (§2.6.7.1 [1]) defines following horizons:

a) Strategic planning which will indicate the predicted traffic situation for chosen times in excess of 20 minutes in advance;

b) Pre-tactical planning which will indicate the predicted traffic situation at a chosen time up to 20 minutes in advance; and

c) Tactical planning which will indicate the present traffic situation.

These ICAO proposed planning horizons should be used as an initial starting point but should not be compulsory when planning horizons are to be adapted to experienced operational needs.

Planning facilities should include methods of predicting an ***aerodrome capacity*** *and indication of* *start-up times* *for traffic to meet this capacity (§2.6.7.2 [1]).*

"… planning will calculate different possible routes for each aircraft and vehicle taking into account the predicted capacities, gate/slot allocation, minimum taxi times and delays. These plans will be modified – steadily reducing time horizons down to pre-tactical planning (typically 20 minutes in advance) (§3.5.8.3 [1]).

Taking these requirements into account in few words; the ATCO should be provided with a most efficient taxi route that consists of **route** (taxi path) and **time information**, whereas the path and times are permanently updated downwards to a tactical planning level.

In order to interact with the automatic routing function, the ATCO must be provided with an interface. A well suitable **human-machine interface** will be a display representing all needed Electronic Flight Stripes (EFS), sorted for out-and inbound traffic, showing all basic flight plan information the ATCO needs plus additional routing information.

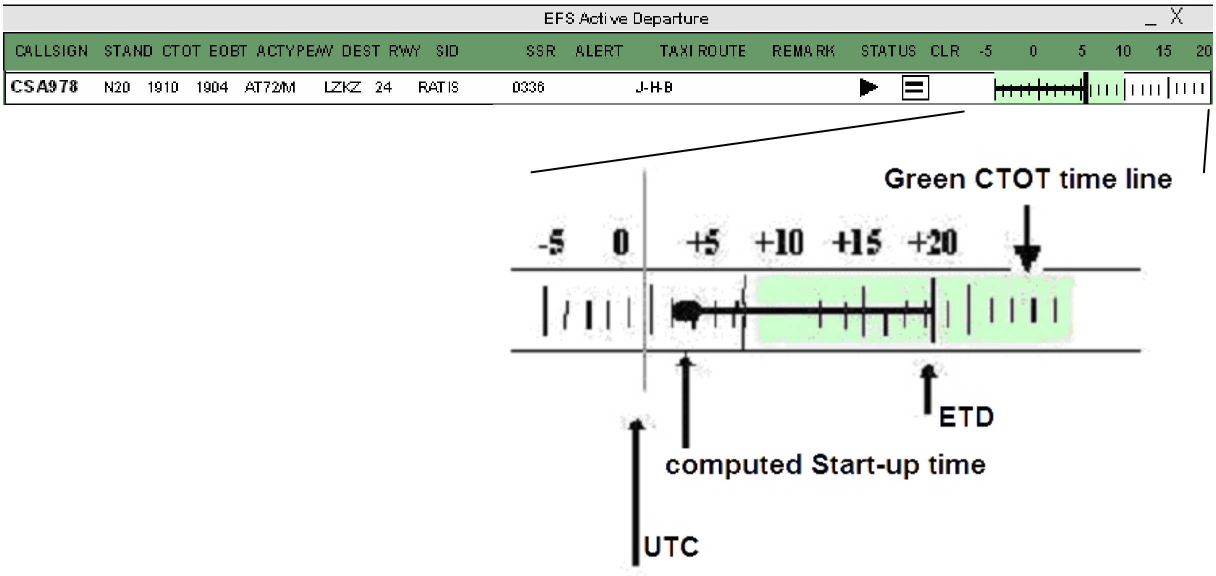
The ATCO can always intervene with this EFS display to set additional constraints unknown to the routing function. The ATCO can also cancel or change the complete route or time information. As mentioned-above, the main interaction with the routing function should be done by an assistant controller (or planning controller) to prevent the executive controller from additional distracting tasks.

The route (path) information should be indicated alphanumerically within the EFS but should also be linked with the surveillance display (on request of the ATCO the route could be presented graphically). Time information for outbound flights could be visualised[15] by a timeline, which contains following information:

- Estimated time of departure (ETD)
- Calculated take-off time (CTOT)[16]
- Computed start-up time

A time line helps the ATCO to monitor the life cycle of a flight and to derive control decisions. The following EFS example represents a possibility how to indicate this information to the controller:

[15] Using a "timeline" to present time information is only a proposal and not mandatory. This can also be done by displaying time information within the EFS in an alphanumerical way. The best setting has to be checked yet.
[16] If allocated to a flight.



(*source: BETA*)

Figure 2-2 - Example for Electronic Flight Strip with route and time information

The ETD comes out of the flight plan data processing system (24h planning) and is used as the target time for the planning process to compute an efficient start-up time (strategic planning). Starting from the ETD, the duration of all preceding events including the time needed to start the aircraft's engine is subtracted from the ETD to compute an efficient start-up time. If no slot restrictions apply to a flight the ATCO is authorised to grant a start-up clearance with pilot request. Route and times are updated by the route / planning function immediately.

Following events has to be taken into account when computing an optimal start-up time:

ETD (CTOT)[17] as the target time	[minus]
- Taxi time	[minus]
- Push back[18] duration	[minus]
<u>- Start-up duration[19], which depends on type of aircraft</u>	
<u>= Computed start-up time</u>	

The taxi time depends on the route lengths and the average speed of the aircraft. For **outbound traffic** following criteria are considered by the routing function:

- Taxi route length, which itself depends on
  - Start point (e.g. Stand/Gate)
  - End point (e.g. assigned runway, RWY entry point [intersection take-off])
  - Local standard routes
  - Optimisation criteria (e.g. minimise taxi time, length, or crossing conflicts)
  - Local taxi restrictions with LVP (e.g. limitations for taxiways)
  - Type of aircraft (some heavy aircraft may be restricted for some taxiway)
  - Closed taxiways, restricted areas, obstacles, temporary hazards

[17] The ETD are usually fixed 24 hours in advance (strategic). Updates of the ETD, new flights plans, and CTOT allocations have to be considered by the planning function.
[18] Only with aircraft parking at gate positions
[19] Start up of engines often happens with pushback simultaneously. Has to be considered.

- Intermediate waypoints (e.g. de-icing, temporary parking positions)
- Heading of aircraft parking on a remote stand[20]

- Average Speed
  - Average speed per taxiway
  - Traffic density on the aerodrome[21]
  - Visibility or weather conditions[22]
  - Average speed of airliners and type of aircraft (optional)[23]

For **inbound traffic** no start-up time needs to be computed. Instead of, the on-block time is computed taking into account the estimated time of arrival (ETA) (strategic planning horizon) that is refined more and more (pre-tactical planning) until the actual time of arrival (ATA) is known (tactical planning starts). The routing function computes the taxi route and the time needed to perform this route. This taxi time is to be added to the ATA to get the computed on-block time (COBT).

The routing function has to check if the intended final parking position (gate/stand) is available, and if not, when it is available. The time when the final parking position is available has to be compared to the COBT or the first point when out- and inbound traffic would conflict each other (e.g. restrictions through one-way taxi lane between the gate fingers). If the times are conflicting, mitigation measures in terms of routing to temporary parking positions or speed advisories to the inbound traffic have to be initialised by the routing function.

Following criteria are considered for an inbound to compute a taxi route and taxi time:

- Taxi route length, which itself depends on
  - Start point (runway exit [type of a/c, surveillance function])
  - End point (Stand/Gate)
  - Local standard routes
  - Optimisation criteria, e.g. minimise taxi time, length, or crossing conflicts
  - Local taxi restrictions with LVP (e.g. limitations for taxiways)
  - Type of aircraft (some heavy aircraft may be restricted for some taxiway)
  - Closed taxiways, restricted areas, obstacles, temporary hazards
  - Intermediate waypoints (e.g. temporary parking positions when final gate/stand is occupied[24])
- Average Speed
  - Average speed per taxiway
  - Traffic density on the aerodrome[25]
  - Visibility weather conditions[26]
  - Average speed of airliners and type of aircraft (optional)[27]

For vehicles (e.g. inspection cars) and towed aircraft, the same criteria are valid except of the *intended position*. The start point comes out of the surveillance function but the intended position has to be input manually, unless there is a flight plan available for those movements.

[20] Usually aircraft park against the wind when possible. Depending on the heading of parked aircraft different taxi routes have to be assigned.
[21] Average taxi speed is expected to be reduced with increasing traffic amount.
[22] Average taxi speed is expected to be reduced with lower visibility conditions.
[23] There might be differences between different airline companies. The effect has to be investigated if it should be considered or not.
[24] If the gate or stand is still occupied the incoming aircraft should be routed to intermediate parking positions first.
[25] Average taxi speed is expected to be reduced with increasing traffic amount.
[26] Average taxi speed is expected to be reduced with lower visibility conditions.
[27] There might be differences between different airline companies. The effect has to be investigated if it should be considered or not.

To provide most efficient taxi routes as described above the routing and planning functions must be able to interact with the

- Flight plan data processing system (to get ETD, ETA, CTOT, RWY, Gate/Stand, A/C Type),
- The A-SMGCS surveillance and (to get position and identification, ETA updates, ATA)
- The A-SMGCS control function (to know about LVP, crossings and all other prevailing constraints), and
- Metrological services (visibility)

The routing function should have different **optimisation criteria** and should allow modifying them by the operator. The operator should be supported to set the most efficient operational ratio of minimising taxi length and taxi times. A further criterion should be the minimisation of crossings conflicts. These optimisation criteria should be able to assign to the overall traffic, groups of them, or even single aircraft, vehicles or towed aircraft.

By aid of the EFS display (see the time line in Figure 2-2) the ATCO can simply estimate if a delayed aircraft asking for start-up would be able to reach its departure slot or not. Appropriate counter measure, e.g. to request a new CTOT, can initialised by the controller in time.

If a tool is available that predicts the **aerodrome capacity** the planning function should address these forecasts. If the predicted traffic demand is endangered to go beyond its predicted aerodrome capacity, start-up times are planned to meet the maximum capacity. The capacity assessment is at least to be based on factors such as weather conditions, serviceability of equipment, closure of sections of the movement area, surface inspection, friction measurements, and snow clearance activities (§2.6.7.2, [1]).

A **validating tool** to prove the computed routes for their operational significance should be established (see §2.5.2.4f, [1]). This tool should check the route for its consistency and validity.

When a **point to point data link** facility is available and the onboard side is properly equipped, taxi routes and other advisory information can be up-linked and graphically displayed to the flight crew and vehicles drivers, which would contribute to avoid misunderstanding by voice communication and thus safer taxi execution. Further on, routing and planning information can easily be transmitted to other controller working position, to airline planning centres, to the gate management or to adjacent control centres. This supports the **CDM** process and the overall planning of movements on the airport and its vicinity[28].

2.1.3.4 Advanced Automatic Routing - Departure and Arrival Management

With §2.5.4.2, [1] the *control function of an A-SMGCS should also provide for:*

a) *Sequencing of aircraft after landing, or of departing aircraft, to ensure minimum delay and maximum utilization of the available capacity of the aerodrome;*

Note: Certainly, sequencing is an aspect of control, but the sources of providing advisory information to this sequencing are the routing and planning function. Therefore, the service of a departure management and aspects concerning arrival management are described in this section.

…For departures, engine start and push-back times can be coordinated and managed to gain optimum departure sequencing, taking into account the planned route.
(§1.3.12, [1])

With the automatic routing function, optimised routes enhanced by the computation of optimal start up times are assigned automatically. However, to increase the overall aerodrome capacity an optimal departure sequence has to be applied. This should be addressed by a departure management tool that provides an optimal departure time for each flight and an optimal overall departure sequence taking into account arrivals, wake vortex categories, CFMU slot, and departure routes (SID).

[28] This support of other services is independent on the level of automation, that is, already possible with manual routing.

A departure management tool (known as Departure Manager [DMAN]) is a planning and decision-support tool which aims to achieve the most efficient departure sequence for aircraft departing at an airport. This leads to a more efficient use of runway capacity, and to a target departure time (TDT) that are more accurate [25]. The DMAN will also identify the optimal departure runway for aircraft at multiple runway airports.

Since Arrival Management is out of authority to the aerodrome controller, this service is not described here. However, A-SMGCS must be able to interface with an arrival management in order to take into account calculated arrival times or even to negotiate in-and outbound traffic for optimal runway occupancy.

Figure 2-3 shows an example of a planning display used by an aerodrome controller (EUROCONTROL DMAN, TRS 025). The electronic flight stripes are arranged in accordance to their departure runway and sequenced by a timeline in accordance to their optimal departure time. This representation provides the aerodrome controller with a good overview about the runway occupancy of departures and arrivals.

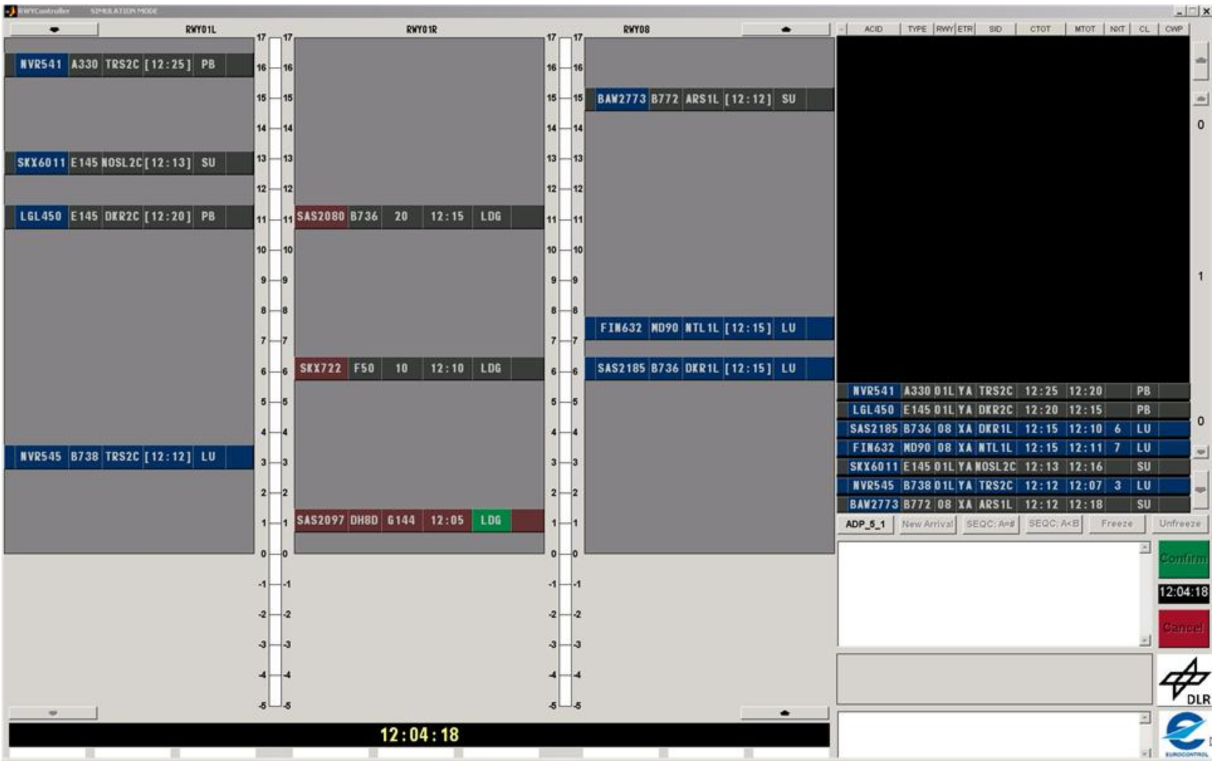


Figure 2-3 - Example of a DMAN planning display used by an Aerodrome Controller

The DMAN calculates an **optimal departure sequence** by taking into account following constraints:

- Arrivals (ETA, ATA)
- CTOT or ETD or confirmed/estimated Off-Block Time
- Earliest ready time (for take-off)
- Separation between aircraft depending on
  - Separation minima (base on wake vortex category, SID, regulations, occupancy time)
- Standard Departure Route (SID)
- Runway(s) in operational use including whether the runway is exclusively used for arrival, departure or both

- Intersection take-offs
- Prioritised flights
- Runway inspections
- Selected planning strategies
- Additional constraints set by the ATCO

Output of the DMAN is an **optimal target departure time (TDT)** that is used by the automatic routing function to compute an optimal start-up time.

In order to get the best benefit of an automatic routing function supplemented with a departure manager, **operating procedures** need to be changed most probably. Strict planning on the basis of "first come first served" can also be managed by an advanced planning tool but with very less benefit in terms of efficiency. To implement an efficient departure sequence the DMAN needs a certain planning horizon. In contrast to nowadays procedures, where the pilot calls in and request the start-up clearance, it must be aimed that an EOBT is negotiated and confirmed between ATC and the airline right in advance to meet both the airline constraints and the DMAN planning. That would lead to a point where the ATCO, in accordance to the computed start-up time, requests the flight crew to start up their engines. Appropriate interfaces have to be designed to support this information exchange.

2.1.3.5 Dependencies with other Services or Systems

To provide most efficient taxi routes as described above the routing and planning functions must be able to interact with the

- Flight plan data processing system (to get ETD, ETA, CTOT, RWY, Gate/Stand, A/C Type),
- The A-SMGCS surveillance (to get position and identification, ETA updates, ATA),
- The A-SMGCS control function (to know about LVP, crossings and all other prevailing constraints), and
- Metrological services (visibility)

2.1.3.6 Quality of Service Aspects

When implementing a routing function, well-designed HMIs and procedures must be used to prevent the executive controller of additional workload and to allow the service to contribute to safety and efficiency w.r.t. surface movements.

Further on with respect to ICAO [1] the routing service should

- provide an optimised route for each participating aircraft and vehicle (§3.4.2.3, [1])
- consider the overall time for an aircraft or vehicle to complete the route in all visibility conditions (§3.4.2.3, [1])
- optimise the traffic flow of aircraft and vehicle surface movements, including aircraft under tow, with respect to:

  a) reducing delay - when planning a route, an effort should be made to permit an aircraft to meet its assigned take-off time or reach its allocated gate on time;

  b) potential conflict - the wing-tip to wing-tip spacing between certain types of aircraft on parallel taxiways should be taken into account;

  c) longitudinal spacing when visibility becomes a factor, including jet blast and propeller/rotor wash;

  d) obstructed, unavailable or temporarily closed parts of the movement area; and

e) taxi speeds (to reduce braking and acceleration, and fuel burn) (§3.4.2.4, [1])

- be able to handle predefined or user-defined intermediate waypoints (e.g. routing through de-icing stations) (§3.4.2.5, [1])
- provide an alternative route on request (§3.4.2.6, [1])
- be possible to immediately cancel or change an existing and used route. In the event that a route is cancelled, a new route to continue should be provided (§3.4.2.7, [1])

Following performance requirements are proposed by ICAO and should be applied with EMMA if no other performance requirements are proved to be more valid:

- Allow one second each for processing and transmission means that the route would be available to the pilot within a few seconds (including controller response time), which should not have a significant impact on operations provided that the route is determined prior to the movement (§3.4.2.8, [1]).
- The processing capacity is related to how many routes can be requested at any one time. The assumption made is that the route request process is random; therefore, over any one-second period, only a small number of routes could be requested. The largest demand will be when there is a large number of scheduled departures closely spaced in time (§3.4.2.9, [1]).
- The time taken to process an initial route should not exceed 10 seconds. Reprocessing to account for tactical changes once the aircraft or vehicle is in motion should not exceed 1 second (§4.3.2, [1]).
- In the processing of optimized routes, the length of taxi distances should be computed to a resolution better than 10 m, and timing to a resolution better than 1 second (§4.3.3, [1]).

2.1.4 Guidance

The ICAO A-SMGCS Manual (Doc 9830 – 2004 [1]) does not provide an explicit definition for the guidance function. The ICAO SMGCS Manual (Doc 9476-AN/927 – 1986 [3]) gives the following description:

> *"Guidance relates to facilities, information and advice necessary to enable the pilots of aircraft or the drivers of ground vehicles to find their way on the aerodrome and to keep the aircraft or vehicles on the surfaces or within the areas intended for their use (§1.1.1)."*

According to the ICAO A-SMGCS Manual, the guidance function is a primary function (§2.2.1 [1]), which should "*provide guidance necessary for any authorized movement and be available for all possible route selections*", "*provide clear indications to pilots and vehicle drivers to allow them to follow their assigned routes*", "*enable all pilots and vehicle drivers to maintain situational awareness of their positions on the assigned routes*" and "*be capable of indicating routes and areas that are either restricted or not available for use*" (§2.5.3 [1]).

Therefore, predominantly, guidance provides services for pilots and drivers, helping them to implement clearances and instructions given by the controller, and preventing them from missing their assigned routes and from intruding restricted areas.

With the conventional SMGCS, guidance to pilots and drivers is provided by:

- Guidelines painted on the tarmac and signposts placed near taxiways and runways
- Airport paper maps used on board
- Instructions and information from the controller via voice radio communication
- Follow-me vehicles
- Runway and taxiway lights, manually switched stop bars

Providing guidance is one of the controller's tasks, namely for ground executive controllers, complementing their planning of ground traffic movements and their control activities in order to have the movements implemented as planned.

Guidance provided by the controllers consist of giving information and advice via voice radio, and, as applicable at a specific airport, directing the follow-me vehicles and switching stop bars, these tasks often performed by assistants.

There is a close interrelation between control and guidance, since both functions aim at having aircraft movements performed as planned. However, a clear differentiation shall be made:

- Control is performed, when the controller issues a clearance or switches a traffic light off or on, which instructs the pilot to perform a taxi operation or to stop.
- Guidance is performed, when the controller gives information or when technical means are activated, which help the pilot or vehicle driver to comply with the clearance given.

For the transition from SMGCS to A-SMGCS, ICAO describes high-level goals for the necessary improvements. Concerning guidance, it states: "*Improved guidance and procedures should be in place to allow: 1) safe surface operations on the aerodrome, taking into consideration visibility, traffic density and aerodrome layout; and 2) pilots and vehicle drivers to follow their assigned routes in an unambiguous and reliable way* " (§1.2 g [1]).

The guidance function shall be automated (see ICAO §1.3.2 [1]). However, "*automated guidance should not be used by the system if aircraft control, conflict detection and conflict alert resolution are not available*" (§2.6.14.3 [1]).

Further, it is stated "*for control staff, the system should have interfaces that allow them to manage the routing, guidance and control functions in a safe and efficient manner*" (ICAO §2.6.15.7 [1]). The reason is that, at any time, the controller will be responsible for the ground traffic management, even when by increased automation human functions are transferred to the system (see ICAO §3.2.2 [1]).

Note: Guidance, being a primary function of the A-SMGCS, is a service dedicated to pilots and vehicle drivers.
For the controllers, the guidance function must provide interface functions, which make it possible to operate and monitor the guidance means.

ICAO mentions two categories of guidance means:

Ground based guidance, for which it says, that "*surface guidance will include improved visual aids for automated guidance and control along the assigned route*" (§ 1.3.9 [1]) and that these "*should be an integrated component of the system*" (§1.2 h [1]).

Onboard guidance, for which ICAO states, "For low visibility conditions, the pilot may need suitable avionics, such as a moving map, to monitor progress and compliance with the assigned route. These avionics may also be used to display surface traffic information" (§ 1.3.9 [1]).

2.1.4.1 Ground based Guidance

This section presents a general concept for ground based guidance. Where the respective functions are available and applicable within the EMMA experimental system, they should be incorporated.

A-SMGCS ground based guidance means should provide visual aids, which will consist of:

- Selectively or segment-wise switched centre line lights, and
- Selectively switched stop bars

The ICAO operational requirements state, that pilots and vehicle drivers should be provided with information on location and direction all the times, and get continuous guidance for all kinds of movements (see §2.6.11 & §2.6.12 [1]). This can not be accomplished by single traffic lights or switched signposts only, which are installed at intersections. However, these can contribute to more efficient and safer guidance.

When the above mentioned ICAO requirements (§2.6.11 & §2.6.12 [1]) should be fulfilled, the taxiways shall be equipped with green centre line lights, which either can be addressed and switched separately, or are grouped in segments and can be switched segment by segment, with red stop bars in between, respectively at the beginning and end of each segment.

ICAO Annex 14, Vol.1, §5.3.15 [23] gives requirements and recommendations concerning the position, spacing and photometric parameters of taxiway centre line lights, so that clear route indications and sufficient visibility for the lights are guaranteed also in low visibility conditions. According to §5.3.17.13 [23], stop bars have to be "*interlocked with the taxiway centre line lights so that when the centre line lights beyond the stop bar are illuminated the stop bar is extinguished and vice versa*".

Guidance by visual aids is applicable for LVO including visibility condition 3, but not for visibility condition 4 with RVR of 75 m or less (see ICAO A-SMGCS Manual appendix A, §2.1 [1]).

According to the level of automation implemented, switching of the visual aids may occur either manually or automatically.

With manual operation, the visual guidance system will be operated via a light board or a display, which shows the topography of the airport movement area and the traffic lights installed as well as their on-off-status, and provides means to switch the lights on and off.

For a taxi route assigned to an aircraft and the respective taxi route clearance issued, the light board operator will switch on the centre line light segments from the actual position of the aircraft up to the intended end of the taxi movement, which will be signalled by a red stop bar. The centre line segment behind the stop bar must remain dark.

With automatic operation provided by a higher-level A-SMGCS, a taxi route generated by the route planning function, displayed to and accepted by the controller via an entry to the system, will trigger the guidance function to automatically switch on the respective centre line segments from the actual aircraft position up to the intended holding position, where the red stop bar is switched on. As a lighted segment is left or the stop bar is reached, the segments behind the aircraft will go dark. Automatic operation as described requires high performance for the surveillance function (see ICAO §2.5.1.1 and §4.2.2 [1])

In any case, whether manually or automatically operated, the controller must be provided with clear indications presenting the guidance provided to the pilot. ICAO §4.4 [1] requires an actuation time inclusive feedback of not more than 2 seconds and a reversion time of 0.5 seconds maximum. A monitoring function must raise an alert, when the visual guidance function fails, deactivate the visual guidance means and protect the runways from access by switching on the stop bars (see §3.4.3.11 [1]).

Ground based guidance by visual aids has the advantage that guidance can be provided to every aircraft or vehicle, independent of the onboard equipage, and that the controller can interact with every aircraft in the same way.

Further, even with manual operation only one system interaction will activate a clear and unambiguous guidance means, which will persist until the aircraft has reached the holding position. For performing visual monitoring of aircraft movements, the ground based guidance function provides direct correlation of the taxi route assigned and the aircraft following the green line, as far as possible by view from the tower.

For pilots the function provides clear, unambiguous, and continuous information by view from the cockpit windows, avoiding head-down operation. It complements the taxi clearance received, and directly shows where to go and when to stop, and thus helps with difficult traffic situations and complex or unfamiliar airports. The pilot will start taxiing when he has received the respective clearance, the stop bar in front of him switches off and the green line lightens. He will follow the green line presenting the cleared route and will stop when reaching a red illuminated stop bar. To make ground movements most efficient, stops have to be avoided unless taxi conflicts or safety restrictions would require a stop of the aircraft or vehicle.

2.1.4.2 Data Link

A further means, which shall be used to make guidance information automatically available onboard the aircraft, shall be data link. By itself, data link is no guidance means, but a transport medium for the respective information. It concerns the functions provided to the ATCO in so far, as an indication is necessary, whether the function is available with a specific aircraft or that other guidance means have to be used.

ICAO states, that "*an A-SMGCS will reduce voice communications*" (§1.3.7 [1]) , and that "*voice communications will migrate into a mix of voice and data link capabilities, with automated data communications between system components providing situation information between the users, including from the ground to the cockpit*" (§1.3.8 [1]).

With more automated functions provided by a higher-level A-SMGCS, when a taxi route for an aircraft has been generated by the route planning function, and has been displayed to and accepted by the controller via the HMI function, the route will be automatically transmitted to the respective aircraft via data link, where it will be displayed graphically by onboard guidance means.

The functionality described requires an interface to the controller, which indicates, whether the automatic transmission of guidance information is possible for a specific aircraft, and a monitoring function which gives feedback whether the transmission was successful or failed.

Further aspects concerning the onboard side are given in chapter 2.2 of this document.

2.1.4.3 Dependencies with other Services or Systems

For automatic operation, the ground based visual guidance function must interact with the routing service, so that an automatically planned taxi route will trigger the guidance function to switch on the respective centre line segments from the actual aircraft position up to the intended holding position, where a stop bar will be switched on.

Likewise an interface to the surveillance function is required, which enables the guidance function to automatically switch off the taxi light segments and switch on the respective stopbars behind an aircraft.

For the automatic transmission of guidance information to the aircraft via data link, the data link based guidance function requires interaction with the routing function, so that a planned taxi route will be automatically transmitted to the aircraft

2.1.4.4 Quality of Service Aspects

For the ground based visual guidance function the following aspects apply:

- The controller must be provided with clear indications presenting the guidance provided to the pilot.
- ICAO §4.4 [1] requires an actuation time inclusive feedback of not more than 2 seconds and a reversion time of 0.5 seconds maximum.
- A monitoring function must raise an alert, when the visual guidance function fails, deactivate the visual guidance means and protect the runways from access by switching on the stop bars (see §3.4.3.11 [1]).
- Taxiway centre line lights have to comply with the requirements and recommendations given in ICAO Annex 14, Vol.1, §5.3.15 [23]
- According to ICAO Annex 14, Vol.1, §5.3.17.13 [23], stop bars have to be "*interlocked with the taxiway centre line lights so that when the centre line lights beyond the stop bar are illuminated the stop bar is extinguished and vice versa*".

For the automatic transmission of guidance information to the aircraft via data link the following aspects apply:

- The controller must be provided with an interface, which indicates, whether the automatic transmission of guidance information is possible for a specific aircraft, and a monitoring function which gives feedback whether the transmission was successful or failed.
- The data link function must provide reliable, fault-free transmissions of data.
- The transmission delay caused by the data link function must be small enough so that the guidance function will comply with the timing requirements given in ICAO §4.4 [1].

2.2 Service to Flight Crews

The automated services provided to the flight crews for surface movements in the context of EMMA project are described in this section.

2.2.1 Surveillance

The surveillance service provides to the flight crews information about the position of the own aircraft with respect to the airport layout, the restricted areas such as active runways as well as the position and identification of surrounding traffic. Such service aims at increasing the situational awareness of the flight crews and improving the efficiency of the surface movements through own-ship positional awareness, especially in low visibility conditions or when the flight crew is not familiar with the airport layout.

The service provides information that augments the flight crews' visual information. The sole use of electronic information for aircraft navigation and collision avoidance on the airport surface is not envisaged within the time frame considered for EMMA operational services (15 years).

The surveillance service has been decomposed in three main ones:

- Airport Layout Awareness: provides information about the position of the aircraft with respect to airport areas (runways, taxiways, apron, stands), for instance runway layout (thresholds, entries / exit), runway status (configuration, active / closed,) and the related protection areas (runway holding positions for CAT-I up to CAT-III)
- Runway Occupancy Awareness (for landing and take-off phases): helps flight crews to visually acquire threatening traffic prior to possible avoidance manoeuvres
- Traffic Situational Awareness: Provide the flight crew with an enhanced traffic situational awareness on the airport surface for both taxi and runway operations...

The service is realised through several on-board functions presented in the following sub-sections.

2.2.1.1 Airport moving Map Function

As mentioned above, ICAO states, that for low visibility conditions, the flight crew may need an airport moving map function to follow the assigned route (see §1.3.9 [1]).

The airport moving map function aims at supplementing the out-of-the window visual assessment of the own-ship situation (horizontal position, heading, and velocity) on airport layout.

The function displays own ship position with respect to aerodrome geographic locations (i.e. geographic features, or ground based facility locations in proximity of the aircraft) and in particular, the aerodrome elements referenced in the ATC instructions.

The function improves situation awareness of the flight crew in regard to aircraft position on the airport layout, and therefore facilitates aircraft navigation on the airport surface. This is particularly true in low visibility conditions and on complex or unfamiliar airports.

2.2.1.2 Ground Traffic Display Function

The ground traffic display function will support the flight crew during surface movement operations. Aircraft surface operations include the movement of aircraft and airport vehicles on aprons, taxiways, and runways. During current operations, control procedures are largely based on visual methods for maintaining separation between aircraft and between aircraft and airport vehicles.

The main goal of the ground traffic display function is to reduce the potential for conflicts, errors and collision with others aircraft / vehicles by providing enhanced situational awareness to the flight crew operating on the airport surface especially in all weather conditions.

The traffic display function mainly includes the following aspects:

- Receive, correlate and merge passive traffic surveillance data coming from different sources (ADS-B, TIS-B)
- Provide the flight crew with the surrounding traffic information (ground/airborne) on an appropriate display

2.2.2 Conflict Detection

The conflict detection service aims at preventing the potential incursions of the own ship in restricted areas (e.g. entry on a closed runway) as well as the risk of collision with other traffic (infringement of protection areas).

Such service raises the awareness of the flight crew about potential hazardous situations by providing appropriate warnings or alarms and by designating such situation on an electronic display or using synthetic voice (e.g. "Crossing runway 25L holding position").

The provision of conflict detection service for both flight crews and ATCOs (part of Control) raises the issue of potential interferences between the alerts issued by the onboard system and the instructions given by ATCOs. Such issue is tackled from operational procedure perspective in the D1.3.5 ORD Update document.

From the onboard perspective the time ahead for alerting of potential hazardous situations is kept relatively short (approx 5-10s) in order to keep the rate of potential false alarms acceptable by flight crews.

The service is realised through several on-board functions presented in the following sub-sections.

2.2.2.1 Surface Movement Alerting function

The surface movement alerting (SMA) function aims to improve the safety and efficiency in aircraft surface movements by providing an alert to the flight crew in case of possible hazardous situations for the aircraft.

The main goals of this function are:

- To avoid collision with fixed obstacles
- To avoid own-ship runway incursions (i.e. incursions caused by own aircraft), including takeoff in wrong direction or from closed runway
- To avoid usage of unsuitable taxiways
- To avoid deviation from
  a) Taxiway guidance line / centre line
  b) Pre-defined route
- To avoid take-off from taxiways

In order to achieve this, the SMA function will provide the flight crew with new types of control information:

- **<u>Runway alerting function</u>**
  - **Runway proximity alerts** in order to inform the flight crew that their aircraft is about to enter a runway.
  - **Runway incursion alerts** in order to anticipate and prevent hazardous situations: the flight crew will be alerted that it is entering a runway it is not allowed to enter (runway closed…). If the flight crew has already entered the runway, the alert will include

instructions to resolve the hazardous situation as soon as possible.

- **Taxiway alerting function**
  - **Taxiway compatibility:** The flight crew will be alerted when the aircraft characteristics (weight, wingspan, jet blast…) are not compatible with the taxiway ones. Two different cases should be envisaged:
    - Compatibility checking all along the assigned route based on ATC data-link uploaded ground path,
    - “Real time” computation when the aircraft is about entering a non-compatible taxiway.
  - **Taxiway safety margins control:** The flight crew will be alerted when the aircraft position on the taxiway is not in accordance with the safety margins defined for this taxiway.
  - **Taxi route conformance:** The flight crew will be alerted when the aircraft is leaving the assigned taxi route.
  - **Taxiway take-off alerting:** The flight crew will be alerted when the groundspeed exceeds a certain value, when the acceleration (or its derivative) approaches values typical for a take-off or when take-off power is set while the aircraft is still on a taxiway.
  - **Fixed obstacle avoidance** alerting: The flight crew will be alerted when a collision with a fixed obstacle impends.

2.2.2.2 Traffic Conflict Detection Function

The function aims to raise the awareness of the flight crew about potential conflict(s) with other traffic as a complement to the runway situational awareness and/or to the traffic situational awareness.

The function performs the detection of such potential conflicts based on traffic information received via ADS-B or TIS-B and determines the appropriate alert level.

An initial list of potential traffic conflicts to be detected by the function is presented in Annex II section 9.5.

2.2.3 Control

The control services aims at supporting the flight crew for the controller – pilot dialogs during ground movements (for arrival and departure phases) and the reception of routing information dispatched by the ground system (e.g. standard taxi routes).

It is not intended to replace voice communications for time critical messages, therefore such service aims first at supporting departure clearance request and response (approx 20 min before estimated time of departure), start-up and push-back clearance request and response (approx 10 min before off-block time) and taxi clearance request and response. It may also cover special airport operations such as requests for de-icing.

The service is realised through several the following on-board function.

2.2.3.1 CPDLC Ground Clearances and Taxi Route Uplink

The CPDLC Ground Clearances Function will support the flight crew during surface movement operations. The concept for the CPDLC Ground Clearances Function is based on a direct communication between the flight crew of the aircraft and its current ATC authority, through Data Link medium. CPDLC Ground Clearances Function is a complement to other parts of the A-SMGCS to make the surface movement easier and safer for the flight crew. It allows avoiding misunderstandings and, assembled with graphical tools; it provides an assistance to guide the aircraft to taxi on manoeuvring areas:

- From the parking stand (gate) to the assigned departure runway holding point
- And from the landing runway exit to the assigned stand (gate)

ICAO states that radio telephony should remain the primary means for issuing tactical instructions, and data link, as a supplement to voice radio communication, may be used for clearances and routing information which is not time critical (see §3.3.3.3b [1]).

2.2.4 Guidance

The guidance service aims at supporting the flight crew for aircraft manoeuvres on airport surface (deceleration, turns, braking). Such service covers the provision of advises for braking and steering actions to be taken by the manipulating pilot as a complement to other parts of the A-SMGCS that provide general surface situation awareness information for use by the flight crew.

At a later stage, on pilot request, and in specific cases, the service ensures the conversion of the guidance information into steering actions to the nose wheel steering, the rudder, the braking system, or the thrust control.

2.2.4.1 Braking and Steering Cues Function

The Braking and Steering Cues (BSC) subsystem is an avionic function that will support the flight crew of an aircraft during surface movement operations. The concept for the BSC function is that it provides tactical support to the flight crew, as a complement to other parts of the A-SMGCS that provide general surface situation awareness information. The BSC function has two roles:

- Braking support to improve the reliability of runway occupancy times during the landing roll, by assisting the manipulating pilot to control aircraft deceleration in order to exit the runway as planned, or to warn the flight crew as early as possible if actual braking performance is not sufficient to exit as planned. In the event that the actual deceleration is insufficient to leave the runway at the planned exit, the BSC function is required to present speed-control cues so that the aircraft can use the next practicable exit with the minimum increase in runway occupancy time.
- Steering and braking support to the flight crew during taxi operations. Examples where the BSC function will contribute to taxi operations include:
- Braking cues in the event that taxi speeds are too high approaching a turn
- Steering cues for taxi manoeuvres
- Speed-control cues to allow the flight crew to increase speed where appropriate to reduce overall taxi time whilst minimising wear and tear on the undercarriage

In order to provide the required support to the flight crew, the BSC function uses information from the aircraft navigation system (position, heading, ground speed…) as well as a database of the airport surface features.

2.2.4.2 HUD Surface Guidance Symbology Function

The Head-Up Navigation Subsystem is an avionic function which serves to support the flight crew of an aircraft during taxi operations. The concept for the Surface Guidance Symbology Function on HUD is that it provides adapted symbology, tactical support to the flight crew, as a complement to other parts of the A-SMGCS that provide general surface situation awareness information.

Within the scope of the EMMA Project, the SGS/HUD function is a concept-demonstrator intended for use only in situations where the flight crew has independent means of verifying the support provided. The SGS/HUD function has to provide to the flight crew Pilot Flying following elements:

- Guidance cues path to follow with stop information (stop bars, traffic stop) associated to ATC clearance
- Awareness information relative to aircraft situation on taxiway
- Additional symbology to represent taxiway limits

- Steering and braking cues to the PF during taxi operations. Examples where the B&SC function will contribute to taxi operations include:
- Braking cues in the event that taxi speeds are too high approaching a turn;
- Steering cues for turn entry and exit information if the visibility is reduced;
- Speed-control cues to allow the manipulating pilot (PF) to minimise wear and tear on the undercarriage whilst maintaining planned taxi timings, etc.

In order to provide the required support to the flight crew, the Surface Guidance function uses information from the aircraft Navigation system (position, heading, ground speed…) as well as from Airport Navigation function, CPDLC Ground Clearance function and B&SC function.

2.2.4.3 Automated Steering

The function covers the performance of steering actions by to the auto-pilot during the taxi movements following the taxi routing, taking into account ATCO clearances and onboard guidance information, like braking and steering cues.

2.2.5 Other airborne functions

Considering the advanced stages of the four services to the flight crews (surveillance, conflict detection, control and guidance), a function which ensures the access to the latest aeronautical information concerning the airport (layout, configuration) is required.

Ground- Air Database Upload
This function covers the update of the airport mapping data available in the aeronautical database on board as well as the NOTAMs not communicated to the flight crews prior to flight and the ATIS information (D-ATIS data link service).

2.2.6 Correspondence with ICAO A-SMGCS Manual

A-SMGCS services to flight crew shall support the safe and expeditious surface movements of the aircraft in compliance with the routing instructions and clearances delivered by ATC Controllers.

The following table depicts the set of services recommended by ICAO Doc 9830 and their realisation by the 6 on-board functions that are explained in the following sub-sections.

	On-board Functions						
Services recommended by ICAO Doc 9830 Section 2.6.11 (Pilot considerations)	Airport moving map including NOTAMS	Surface Movement Alerting Traffic Conflict Detection	Ground traffic display	CPDLC clearances and taxi route uplink	HUD surface guidance symbology	Braking and steering cues	Remarks
a) information on location and direction at all times;	Own-ship position and heading with respect to airport layout						
b) continuous guidance and control during the landing roll-out, taxiing to the parking position and from the parking position to the runway-holding position, to line up at any take-off position and the take-off roll;	Own-ship position and heading	Proximity of obstacles and other traffic (below threshold value)		ATC Clearances			
c) indication of the route to be followed, including changes in direction and indication of stops;	Taxi route displayed			ATC Clearances for taxi route			
d) guidance in parking, docking and holding areas;	Own ship position and map						Guidance also provided by signs, marking and lighting

	On-board Functions						
Services recommended by ICAO Doc 9830 Section 2.6.11 (Pilot considerations)	Airport moving map including NOTAMS	Surface Movement Alerting Traffic Conflict Detection	Ground traffic display	CPDLC clearances and taxi route uplink	HUD surface guidance symbology	Braking and steering cues	Remarks
e) indication of spacing from preceding aircraft, including speed adjustments;			Only reported position of the preceding aircraft (complement to visual information)				Spacing and speed adjustment to avoid collision with other traffic not provided by the system
f) indication of spacing from all aircraft, vehicles and obstacles in visibility condition 4;	Presence of fixed obstacles	Proximity of obstacles and other traffic (below threshold value)	position and identity of other traffic				
g) indication of the required sequencing;							Provided by the ATCO to the pilot via voice (critical information)
h) information to prevent the effects of jet blast and propeller/rotor wash;		Incompatibility between the taxi route and the aircraft type detected					Known by pilots
i) identification of areas to be avoided;	closed or restricted areas displayed						
j) information to prevent collision with other aircraft, vehicles or known obstacles;	Position of fixed obstacles	Proximity of obstacles and other traffic (below threshold value)	position and identity of other traffic				
k) information on system failures affecting safety;							Failures of on-board system will be notified to the pilot
l) the location of active runways;	Mapping information						
m) alert of incursion onto runways and taxiways;		proximity of runways					

	On-board Functions						
Services recommended by ICAO Doc 9830 Section 2.6.11 (Pilot considerations)	Airport moving map including NOTAMS	Surface Movement Alerting Traffic Conflict Detection	Ground traffic display	CPDLC clearances and taxi route uplink	HUD surface guidance symbology	Braking and steering cues	Remarks
n) the extent of critical and sensitive areas.	mapping information						Information also provided by marking (e.g. ILS Cat I / Cat III holding positions)

Table 2-1: Service to flight crews – Correspondence ICAO - EMMA

2.2.7 Dependencies with other Services or Systems

This section identifies the list of the dependencies with other A-SMGCS services and with external systems that are required for the provision of the service

- Ground traffic context information (Aeronautical Information) updated before or during flight
- Routing Service : for the determination of the taxi route assigned to the flight (see in 2.1.3)
- CPDLC ground station: to obtain the approval from the concerned ATC Controller of the departure clearance, the taxi clearance requests, the routing instruction…
- TIS-B for uploading identity-position-state vector of non-ADS-B aircraft
- Aeronautical Information server on the ground for the database upload

2.2.8 Quality of Service Aspects

This section describes briefly the main aspects from the user's perspective for the quality of service to be provided.

- Accuracy of the airport mapping information and correctness of the taxi guidance instructions issued by the on-board system
- Correctness and timeliness of alarms generated by the Surface Movement Alerting and Traffic Conflict detection on-board functions
- Accuracy and integrity of surrounding traffic identification and positioning
- Ease of use of the CPDLC function for taxi movements
- Efficiency of braking and steering actions in order to reduce runway occupancy time and for smooth taxi movements
- Consistency and practical usefulness of HUD symbology

2.3 Service to Vehicle Drivers

According to ICAO doc. 9830 (A-SMGCS Manual) chapter 2 (Operational requirements), paragraph 2.6.12 – Vehicle driver considerations - vehicle drivers should be provided with the following services:

a) Information on location and direction at all times

b) Indication of the route to be followed

c) Guidance along the route being followed or guidance to remain within designated areas

d) Information, and control when and where appropriate, to prevent collision with aircraft, vehicles and known obstacles; and

e) Alert of incursions into unauthorized areas

In addition to these services, the drivers of emergency and operational vehicles should be provided with:

a) The capability to locate the site of an emergency within the displayed range of the system; and

b) Information on special priority routes

In Chapter 3 of the ICAO doc. 9830 (Guidance on the application of the operational and performance requirements) the following vehicle driver considerations are laid down in paragraph 3.5.15:

A vehicle driver operating on the movement area, with the exception of passive and empty stands and controlled taxiway crossings should be provided with radiotelephony capability and adequate information to enable the driver to operate the vehicle in all operational conditions, with the knowledge that the system will prevent a collision with aircraft and vehicles.

Specific positive measures should be provided to prevent incursion by vehicles onto an active runway under any visibility conditions.

Specific positive measures should be provided to prevent incursion by unauthorized vehicles onto the movement area.

The system should provide guidance and control for rescue and fire fighting vehicles in order for them to reach any point on the movement area within the required response time. The system should also provide for operational vehicles that carry out essential duties on the movement area, e.g. surface inspections, bird control, de-icing and snow clearance.

Authorized vehicles permitted only on apron roads (including controlled and uncontrolled crossings), and passive and empty stands should not be subject to control by an A-SMGCS.

Facilities should be provided for the drivers of all vehicles to be aware of their proximity to the movement area. Additionally, facilities should be provided for the driver of each controlled vehicle to be aware of:

a) The location and direction of the vehicle on the movement area;

b) The assigned route to follow, in particular, when that route includes taxiways and/or runways;

c) The relative proximity of any possible conflict on the movement area;

d) The location of any active runway;

e) The extend of runway clear and graded area and strip; and

f) The extend of navigation aid critical and sensitive areas

In most circumstances, situational awareness could be provided by the use of standard lighting, markings, and signage.

All vehicle drivers who are required to drive on the movement area should receive formal training and certification that they are qualified to drive the types of vehicles or equipment they will operate. Such training should include all rules and procedures applicable to the aerodrome and knowledge of those aspects of an A-SMGCS which apply to vehicle drivers, including the use of radiotelephony, when applicable.

All vehicle drivers who are required to drive on the movement area need to be tested to ensure that they meet the necessary medical requirements, including hearing and colour vision.

2.3.1 Airport Moving Map Function (Surveillance)

In order to provide the services to vehicle drivers, defined in the ICAO A-SMGCS Manual, it is necessary to equip vehicles, which will be used for operation on the movement area (with the exception of passive and empty stands and controlled taxiway crossings) with an airport moving map function. This function is necessary in particular for operation under low visibility conditions and for operation at airports with complex runway and taxiway layout situations.

The airport moving map function aims at supplementing the out-of-the-window visual assessment of the vehicle position on the airport layout. The airport moving map function displays the vehicle position with respect to aerodrome geographic locations (i.e. geographic features, or ground based facility locations in proximity of the aircraft) and in particular the aerodrome elements referenced in the ATC instructions.

The airport moving map function allows the vehicle driver to determine the actual position of his vehicle on the airport surface. Especially in low visibility conditions and under complex airport layout situations the use of the airport moving map function will significantly increase the situational awareness of the vehicle driver.

2.3.2 Surface Movement Alerting Function (Control)

The surface movement alerting (SMA) function aims to improve safety and efficiency in surface movements. This function aims to provide an alert to the driver in case of possible risk situations for the vehicle. In order to provide the full range of services to vehicle drivers, which have been identified by ICAO (see section 2.3), this function should be used for vehicle drivers, which operate on the movement area, too.

The surface movement alerting function should be used in vehicles, operating on the movement area:

- To avoid collision with fixed obstacles
- To avoid runway incursions of vehicles, operating on the movement area
- To avoid entry of taxiways, which have not been authorized for use by ATC (tower)
- To avoid deviation from pre-defined routes on the movement area, issued by ATC (tower)

In addition emergency actions for vehicle drivers may be advised by the system ("stop" or "leave runway") taking the benefit that vehicles can easily vacate runways or taxiways at any point (moving on the grass).

Similar to the flight crew, the SMA function will provide the vehicle driver with new types of control information:

- **Runway alerting function:**
  - **Runway proximity alerts** in order to inform the vehicle driver that he is about to enter a runway.
  - **Runway incursion alerts** in order to anticipate and prevent hazardous situations: the vehicle driver will be alerted if he is entering a runway that he is not allowed to enter (departing or arriving traffic on runway). If the vehicle driver has already entered the runway, the alert will

include instructions to resolve the hazardous situation as soon as possible.

- **Taxiway alerting function**
    - **Taxi route conformance:** The vehicle driver will be alerted when his car is leaving the assigned taxi route.
- **Fixed obstacle avoidance alerting function**
    - **Fixed obstacle alerting:** The vehicle driver will be alerted when a collision with a fixed obstacle impends.

2.3.3 Ground Traffic Display Function (Surveillance)

The ground traffic display function will support the vehicle driver during operation on the movement area. During current operations, control procedures are largely based on visual methods for maintaining separation airport vehicles and aircraft.

The main goal of the ground traffic display function is to reduce the potential for conflicts, errors and collision with others aircraft / vehicles by providing enhanced situational awareness to the vehicle driver operating on the airport surface especially in all weather conditions.

The traffic display function mainly includes the following aspects:

a) Receive, correlate and merge passive traffic surveillance data coming from different sources (ADS-B, TIS-B)

b) Provide the vehicle driver with the surrounding traffic information (ground/airborne) on an appropriate display

c) Detect potential conflict with other aircraft / vehicle (and associated alert means)

2.3.4 Vehicle Dispatch and Guidance by Data Link

This function covers the provision of vehicle dispatch information (to stand or aerodrome areas) as well as specific guidance information to individual vehicles using data link communications.

2.3.5 Remarks on Vehicle Equipage

A distinction needs to be made between vehicles, operating on the movement area, and vehicles, operating only on apron areas. While the first category of vehicles needs to be equipped with the above described functions, the second category of vehicles does not necessarily needs to be equipped with these functions.

Vehicles operating on apron areas only do not need to be equipped with these new functions for the following reasons:

- Very often these vehicles operate on special roads and special apron areas independently from ATC and apron control clearances and not being in radio contact with them
- Equipage of these vehicles would dramatically increase costs for apron services due to the high number of vehicles that should be equipped
- The high number of targets on the apron areas would lead to an overlay of targets on the display and to a possible overload of the system capabilities.

System capability aspects also need to be considered when talking about vehicles that cross parts of the moving area (taxiways or runways) and then operate on areas which are close to runways and taxiways, but outside the safety strips of them. One example would be mowers that operate between runways. In order to avoid overlay of targets and system overloads it is imaginable that those vehicles are equipped with the new functions, drivers switch on the displays and transponders when they require a clearance to drive on parts of the movement area, but switch off their system when operating outside runways, taxiways and dedicated safety strips.

2.3.6 Dependencies with other Services or Systems

This section identifies the list of the dependencies with other A-SMGCS services and with external systems that are required for the provision of the service.

- Vehicle driver must be provided with position information of his own position and the position of aircraft and other vehicles close to his own position (moving map). Position information needs to be provided from the A-SMGCS surveillance.
- Restricted areas or closed parts of the movement area need to be displayed on the ground traffic display. These data should be obtained from the control tower, as far as ATC will make the necessary inputs
- Fixed obstacles need to be displayed on the ground traffic display. These data will be obtained from the aeronautical information server / ground data base.
- Clearances to drive onto parts of the movement area can be given to the driver via voice communication with the tower or via datalink (CPDLC).

2.3.7 Quality of Service Aspects

This section identifies briefly the main aspects from the user's perspective for the quality of service to be provided for the vehicle driver.

- Position information of the own position of the vehicle and of the position of aircraft / vehicles close by must be provided in real time. Update rate should be high (less than 2 seconds), as far as vehicles on the movement area sometimes use speeds which are significantly higher than speeds of taxiing aircraft. Speeds of about 100 km/h are reached during runway check, friction measurements, and emergency situations (fire trucks, rescue cars).
- If datalink is used to deliver clearances to drive onto parts of the movement area it should be guaranteed, that those clearances and instructions are received form the vehicle driver without delay (response times of less than one second)
- Runway incursion alerts and alerts of infringements of unauthorized parts of the movement area as well as alerts about danger of collision with fixed obstacles should be provided in less than one second, this due to possible high speed of the vehicles (up to 100 km/h).

3 Steps for EMMA Services

The section presents a proposal for a stepwise implementation of each service presented in section 2.

First for each service the technical enablers either from ground or on-board systems are identified.

Second the respective steps for each service are identified by considering the technical enablers of the services both on the ground or on-board, determining increasing levels of complexity, integration and certification (or safety assurance) as well as considering the required changes to operational procedures (for ATCOs or Flight Crews).

A third step was to group services and technical enablers in order to establish successive implementation steps that base on:

- Development status of the service (already validated by operational life trials or under investigation through simulation or only at the stage of a concept)
- Development status of the technical enabler (standardised, on the market or to be developed yet)
- Degree of interrelations to other functions (complexity)
- Quality of the enabling equipment (needed reliability)
- Impact on current operational procedures and size of the changes
- Cost/benefit considerations

3.1 Services to ATC Controllers (ATCOs)

3.1.1 Surveillance Service

3.1.1.1 Equipment consideration

The following table depicts the set of technical enablers that are required for the provision of the surveillance service to ATCOs.

Function	On-board Enabler	Ground Enabler
Provide traffic information	• ADS-out or mode S	• Cooperative sensors (Mode-S Multilateration, SSR) • Non-cooperative sensors data fusion • TIS-B • Flight information • Vehicle information
Provide traffic context		• Aeronautical info server • Meteorology
Interface with user		• HMI component

Table 3-1: Equipment consideration for Surveillance Service to ATCOs

3.1.1.2 Steps for the Services

ICAO defines the surveillance function globally and calls for its one-step implementation.
Instead the one step implementation, a progressive process, subject to comprehensive validation, would be a more appropriate approach.
In some cases, depending on the particular situation (aerodrome layout, traffic density) combinations and overlaps within the proposed steps may also be considered.

An approach for the implementation of this function shall be performed by considering the increasing levels of complexity – integration – certification for supporting equipments as well as the potential changes in procedures for ATCOs and Flight Crews

The main steps that the surveillance service is divided could be the indicated in the table 3-2 in this document. This division is made following these considerations:

1. - The first step refers to manoeuvring area only, where the visibility could be restricted (distance tower-manoeuvring area, shades of vision due to obstacles) and for safety (this cold be the most critical area).

2. - The second extends to the zone of movement, ´but exclusively to aircrafts. This is due to the cost that would suppose to extend it to all the vehicles

3. - The third one extends to all vehicles, but as it states the ICAO doc 9830:“It is not practicable to exercise total control over all traffic on the movement area. On the apron, an A-SMGCS applies only to those areas where manoeuvring aircraft may come into conflict with each other or with vehicles”. Then the extensions will be only in this area and in low visibility conditions

Service Steps	Description	Comments
Step 1	• Detection and accurate position of all aircraft in the manoeuvring area • Detection and accurate position of all vehicles in the manoeuvring area • Detection and accurate position of obstacles in manoeuvring area • Identification of all cooperative aircraft in manoeuvring area • Identification of all cooperative vehicles in manoeuvring area	All movements on the manoeuvring area have to be authorised by aerodrome controller (§7.5.3.2.1 [20]). With EMMA all authorised movements shall be properly equipped to enable automatic identification. All other movements are intruders or obstacles There might be authorised aircraft on the manoeuvring area that are not properly equipped to be identified automatically (e.g. in case of transponder failure). Procedures to cover such exceptional cases have to be derived.
Step 2	• Step1 + Detection and identification of all aircrafts in movement area	There might be authorised aircraft (e.g. VFR) on the movement area that are not properly equipped to be identified automatically. Those aircraft are an exception but procedures have to be derived to cope with those aircraft too

Service Steps	Description	Comments
Step 3	• Step2 + Detection and identification of all vehicles in movement area (where manoeuvring aircraft may come into conflict with each other or with vehicles) • Detection of Obstacles in movement area	ICAO doc 9830 §3.5.16.3 "It is not practicable to exercise total control over all traffic on the movement area. On the apron, an A-SMGCS applies only to those areas where manoeuvring aircraft may come into conflict with each other or with vehicles. Therefore, one requirement is to restrict the movement of vehicles on the apron to designated areas and routes. It is also necessary to keep service vehicles away from an active stand. This can be achieved by having painted lines that outline the areas to be left clear when a stand is active. Alternate means of protecting an active stand might become available as a result of technology." Those restrictions to apron areas where manoeuvring aircraft may come into conflict with each other or with vehicles are particularly needed in low visibility conditions, when movements are not able to avoid each other. Movements, which uses those apron areas, should be co-operative to get identified automatically on the ATCO surveillance display and should be equipped with an onboard display showing the own position and position of other aircraft to avoid conflicts.

Table 3-2: Steps for the Surveillance Service to ATCOs

3.1.2 Control Service

3.1.2.1 Equipment consideration

Function	On-board Enabler	Ground Enabler
Conflict and Incursion Detection and Alerting		• Surveillance function (traffic information and traffic context) • Multilateration Systems
Conflict Resolution		• Switchable stop bars • HMI component (alerting & resolution guidance)
Support to Ground Clearances	• CPDLC	• CPDLC • HMI component for clearances input
Support to coordination between ATCOs		• Flight Data Management • Electronic Flight Strips

Table 3-3: Equipment consideration for Control Service to ATCOs

3.1.2.2 Steps for the service

ICAO defines the control function globally and calls for its one-step implementation. Instead, a progressive implementation process subject to comprehensive validation is deemed a more appropriate approach.

In some cases, depending on the particular situation (aerodrome layout, traffic density) combinations and overlaps within the proposed steps may also be considered.

An approach for the implementation of this function shall be performed by considering the increasing levels of complexity – integration – certification for supporting equipments as well as the potential changes in procedures for ATCOs and Flight Crews. As stated in 2.1.2.1 in this document, conflict priorities should be as follows:

- runway conflicts;
- taxiway conflicts
- and apron/stand/gate conflicts;

Thus, the main steps that the control service is divided could be the indicated in the table 3-4 this document. This division is made following these considerations:

1. - The conflicts detected in this step address runway conflict which are the most critical in safety terms (the runway represent the area whit the highest risk of catastrophic event §3.4.5.10 [1])

2. - In the second one, the conflicts detected are taxiway conflicts (following the priority defined in §3.4.5.10 [1]).

3. - The third one, involves transfer coordination and, additionally, the clearances should be provided in this step to reduce the ATCO workload. Data link and associated equipment are necessary

Note: The provision of conflict resolution advisories may be initiated at any step of the control service

Service Steps	Description	Comments
Step 1	• Runway Conflict/Incursion detection and alerting of: 1. aircraft arriving to, or departing on, a closed runway; 2. arriving or departing aircraft with traffic on the runway (including aircraft beyond the runway-holding positions); 3. arriving or departing aircraft with moving traffic to or on a converging or intersecting runway; 4. arriving or departing aircraft with opposite direction arrival to the runway; 5. arriving or departing aircraft with traffic crossing the runway; 6. arriving or departing aircraft with taxiing traffic approaching the runway (predicted to cross the runway-holding position); 7. arriving aircraft with traffic in sensitive area (when protected); 8. aircraft exiting the runway at unintended or non-approved locations 9. unauthorized traffic approaching the runway; 10. unidentified traffic approaching the runway Taxiway Conflicts detection and alerting of: 11. aircraft on a closed taxiway; 12. aircraft taxiing with excessive speed; 13. crossing of a lit stop bar;	. Conflict & incursion detection for infringements into restricted areas, runways by either aircraft or vehicles. The priority in this step is determined by safety terms.
Step 2	• Taxiway Conflict/Incursion detection and alerting of: 1. arriving[29] aircraft exiting runway at high speed with converging taxiway traffic; 2. 3. aircraft approaching stationary traffic; 4. aircraft overtaking same direction traffic; 5. aircraft with opposite direction traffic; 6. aircraft approaching taxiway intersections with converging traffic; 7. aircraft exiting the taxiway at unintended or non-approved locations; 8. unauthorized traffic on the taxiways, 9. unidentified traffic on the taxiways and	Step 2 takes in consideration the taxiway conflicts which are less critical than the runway ones.

[29] ICAO doc. 9830 considers this as a runway conflict

Service Steps	Description	Comments
Step 3	• Detection of plan deviation • Support to Ground Clearances and ATCO coordination	Safety net functionality, short term deviation detection when an unauthorised incursion into restricted areas, runways and taxiways by either aircraft or vehicles is predicted to take place Automated clearance support and transfer co-ordination between both ground / tower and approach / tower. The clearances shall be automated via data-link in order to reducing the ATCO workload. At this point the CPDLC should be implemented (see 3.2.1.1 this document)
Step 4	• Conflict/Incursion detection and alerting of apron/stand/gate conflicts 1. aircraft movement with conflicting traffic; 2. aircraft movement with conflicting stationary objects; 3. aircraft entering/exiting the apron / stand / gate area at unintended or non-approved locations; 4. unidentified traffic in the apron / stand / gate area.	Only the movements in the apron which could be threats to aircrafts movements shall be covered. Automatic predicted / actual conflict resolution or on request from the controller, provide guidance for the most suitable resolution in all visibility conditions

Table 3-4: Steps for the Control Service to ATCOs

3.1.3 Routing Service

3.1.3.1 Equipment consideration

Routing equipment mainly focuses on proper routing and planning algorithm (software). A more challenging task will be to get appropriate interfaces to the needed A-SMGCS internal and external information sources, like surveillance, control, flight plan data processing system, etc.). With manual routing, a proper input device has to be provided: Input devices could be a PC mouse, touch screens, or even speech recognition.

Function	On-board Enabler	Ground Enabler
Manual Routing	None	• Input Devices + • simple routing algorithm
Semi-automatic Routing	None	• Routing algorithm + • Interfaces to external data
Automatic Routing	None	• Routing algorithm + • Interfaces to external data • Planning algorithm (SU-time, DMAN)

Table 3-5: Equipment consideration for Routing Service to ATCOs

3.1.3.2 Steps for the service

With routing four steps deem to be reasonable when implementing routing with an A-SMGCS. The proposed levels of implementation are very much related to routing's level of automation because the higher the level of automation the more

- Information from other functions is needed (surveillance, flight plan data processing system, meteo, ...),
- Reliability has to be increased, and
- Support of a planning function is needed,
- Procedures have to be adapted / changed.

Step 1 "Manual Routing" is rather independent on other services and can be implemented as soon as an A-SMGCS user interface (surveillance display, flight strip display) is available. With **Step 2** (Semi-automatic routing" interfaces to flight plan data processing system, surveillance and control services have to be established to get additional advisory information to provide a most suitable route to the ATCO. **Step 3** has been implemented when routing is supported by time information provided by a planning function that can be further refined with a departure manager function with step 4. **Step 4** is the most sophisticated implementation solution and is mainly intended for the major hubs of the world's largest airports. Most probably standard procedures have to be adapted or even changed in order to enable automatic planning to be most effective.

Service Steps	Description	Comments
Step 1	Manual Routing	Manual input of a route supported by the shortest taxi route w.r.t. to local standard routes
Step 2	Semi-automatic Routing	Routing service proposes a most suitable route, taking into account control and flight plan information.
Step 3	Automatic Routing	Routing service provides route (track) and time information by aid of a planning function.
Step 4	Automatic Routing + Optimisation of runway resource[30]	Planning support is further increased by a departure manager providing optimal departure times and sequences. Procedures are supposed to be adapted.

Table 3-6: Steps for the Routing Service to ATCOs

[30] Tools to support planning of runway use such as DMAN may also be implemented without a pre-existing "routing" function.

3.1.4 Guidance Service

3.1.4.1 Equipment consideration

When in an A-SMGCS ground based guidance means shall come into use, the taxiways have to be equipped with green centre line lights, which either can be addressed and switched separately, or are grouped in segments and can be switched segment by segment, with red switchable stop bars at the intersections, respectively at the beginning and end of each segment.

A lighting control system serves for switching groups of centre line lights and interlocked stop bars on respectively off, and for monitoring purposes. A controller or operator HMI, either a switchboard or a lighting display, allows the manual interaction with the lighting control system, and shows the on-off status of the traffic lights as well as the operability status of the system.

Depending on the level of automation provided by the A-SMGCS, the centre line lights and stop bars will be operated manually or automatically. For manual operation, the controller or lightboard assistant will switch the traffic lights manually via the HMI, in accordance to the cleared taxi route. For automated operation the automated lighting control system will switch the traffic lights in accordance to the cleared taxi route obtained from the control function, and with respect to the actual aircraft position received from the surveillance function.

Ground based guidance gives direct visual information to the pilot by view from the cockpit windows, and thus is independent on on-board enablers.

Function	On-board Enabler	Ground Enabler
Manual Operation of Ground based Guidance Means	None	• Controller HMI (Switchboard or Lighting Display), • Airfield Lighting Control System, • Selectively switchable Centre Line Lights and Stop Bars
Automatic Operation of Ground based Guidance Means		• Controller HMI (Switchboard or Lighting Display), • Interfaces to Control and Surveillance Function, • Automatic Airfield Lighting Control System, • Selectively switchable Centre Line Lights and Stop Bars

Table 3-7: Equipment consideration for Guidance Service to ATCOs

3.1.4.2 Steps for the service

When in an A-SMGCS ground based guidance means shall come into use, mainly two steps of implementation have to be considered, which concern the levels of automation.

In the first step the centre line lights and the stop bars are switched by manual entries at the controller / operator HMI. This does not require the integration of the guidance function with the control and surveillance function.

Manually operated equipment is available today and already in use at several airports.

In the second step the operation of the centre line lights and the stop bars occurs automatically. This requires, that the guidance function interfaces with the control and surveillance functions, receives the cleared taxi route and the position for the respective aircraft, and automatically switches the respective centre line lights and interlocked stop bars on respectively off, and likewise shows the respective information at the HMI.

A further dimension of stepwise implementation may be to equip in the beginning only specific taxi routes, which then are used in low visibility operations except for visibility condition 4. Later on, the implementation may be extended to all taxi routes, and provide ground based guidance for all taxi movements and also in good weather conditions.

In comparison to the implementation of switched centre line lights a less expensive step might be the implementation of manually or automatically switched direction signs together with stop bars. However it is questionable whether this fulfils the ICAO requirements sufficiently, for the reasons given in chapter 2.1.4.2 of this document, as ICAO requires permanent guidance information (see §2.6.11 and §2.6.12 [1]).

Service Steps	Description	Comments
Step 1	• Manual Operation of Ground based Guidance Means	Equipment available on the market.
Step 2	• Automatic Operation of Ground based Guidance Means	Automatic generation of guidance information, based on the cleared route and the actual position of the aircraft.

Table 3-8: Steps for the Guidance Service to ATCOs

3.2 Service to Flight Crews

3.2.1 Equipment Consideration

The equipment enabling the proposed service to Flight Crews varies depending on the function considered.

As the first function proposed in section 2.2. the Airport Moving Map does not require changes to existing avionics equipment nor link to ground systems but the addition of airport mapping data in the on-board aeronautical database and to reuse position information already available.

The following table depicts the main technical enablers of the service to flight crew and following the decomposition of such service presented in section 2.2.

Function	On-board Enabler	Ground Enabler
Airport Moving Map	• Own-ship position and state vector • Aeronautical database (airport layout)	
Surface Movement Alerting	• Own-ship position and state vector • Aeronautical database (layout, obstacles, RWY or TWY closed) • Taxi route, allocated stand or assigned take-off runway for detection of deviations	
Ground Traffic Display	• ADS-B-in • Airport Moving Map	• TIS-B (non ADS-B aircraft, vehicles)
Traffic Conflict Detection	• ADS-B-in • Own-ship position and state vector • Aeronautical database (airport layout)	• TIS-B (non ADS-B aircraft, vehicles)
Ground / Air Database Upload	• Aeronautical database	• Airport Mapping Database server • X-NOTAM • D-ATIS
CPDLC Ground Clearances and Taxi Route Uplink	• CPDLC (DCL, D-Taxi) • Airport Moving Map	• CPDLC • Routing service
Braking and Steering Cues	• Own-ship position and state vector • Taxi-Route (up linked or not) • Aeronautical database (airport layout)	
HUD Surface Guidance	• Taxi Route (up linked or not) • Own-ship position and state vector • Aeronautical database	

Function	On-board Enabler	Ground Enabler
Automated Taxiing	• Taxi Route (up linked or not) • Own-ship position and state vector • Auto-Pilot and Auto-Brake for taxiing	

Table 3-9: Equipment consideration for Service to Flight Crews

3.2.2 Steps for the Service

4 main incremental steps for the service to flight crews have been identified by comparing the different functions, the rationale for the steps is the following:

- Step 1 : no change to existing on-board equipment, no new data link services
- Step 2 : addition of new data link services
- Step 3 : integration of surveillance-guidance information provided to the flight crews (preceding steps) and change to the procedures for coordination between them
- Step 4 : taxi movements are performed by the auto-pilot, which implies major new developments in equipment and procedures

The following table depicts the 4 steps:

Service Steps	Description	Comments
Step 1	• Airport Moving Map • Surface Movement Alerting (initial, incl. proximity of obstacles – runway) • Braking and Steering Cue (for landing roll)	Equipment already available
Step 2	• Ground Traffic Display • CPDLC Ground Clearance and Taxi Route Uplink • Ground-Air Database Upload • Surface Movement Alerting (taxi route deviation) • Traffic Conflict Detection • Braking and Steering Cue (landing roll and taxi)	Changes to the ground system required
Step 3	• HUD Surface Guidance	HUD is already available for approach
Step 4	• Automated Steering	Major changes in equipments and procedures

Table 3-10: Steps for the Service to Flight Crews

3.3 Service to Vehicle Drivers

3.3.1 Equipment Consideration

The equipments enabling the proposed service to Drivers vary depending on the function considered.

The following table depicts the main technical enablers of the service to driver and following the decomposition of such service presented in section 2.3

Function	On-board Enabler	Ground Enabler
Airport Moving Map	• Own position determination • Aeronautical database (airport layout, protected areas)	•
Surface Movement Alerting	• Conflict Detection (conflict caused by the vehicle alone)	•
Ground Traffic Display	• ADS-B-in • Airport Moving Map	• TIS-B (non ADS-B aircraft, vehicles)
Traffic Conflict Detection	• Ground/vehicle datalink	• Conflict and Incursion • Detection and Alerting services Ground/vehicle datalink to upload alerts
Support to Vehicle Operations (fleet planning, locate emergency or operation site, …)	• Ground/vehicle datalink • Airport Moving Map • Aeronautical database	• Ground/vehicle datalink

Table 3-11: Equipment consideration for Service to Drivers

3.3.2 Steps for the Service

3 main incremental steps for the service to driver have been identified by comparing the different functions, the rationale for the steps is the following:

- Step 1 : basic services (on-board enablers only without data link)
- Step 2 : addition of new data link services
- Step 3 : addition of fleet management services

The following table depicts the 3 steps:

Service Steps	Description	Comments
Step 1	• Airport Moving Map • Surface Movement Alerting (vehicle alone)	No ground equipment Local service
Step 2	• Surface Movement Alerting (complete) • Ground Traffic Display Traffic Conflict Detection	New data link services Conflict detection done on ground side then alert upload
Step 3	• Dispatch and Guidance by data link	Major changes in equipments and procedures

Table 3-12: Steps for the Service to Drivers

4 Expected Benefits, Anticipated Constraints and Associated Human Factors

This section contains a qualitative description of benefits, constraints, and human factors identified for EMMA services considering the viewpoint of several airport stakeholders.

4.1 Expected Benefits

This section describes potential qualitative benefits that an airport could receive from the application of A-SMGCS services to ATC Controllers, Flight Crews, and Vehicle Drivers.

The strategic objectives of the surveillance function are primarily to maintain or even increase safety, particularly in low visibility conditions, and to make airport system more efficient. However, the safety improvement realised by a surveillance function cannot ensure that an ATCO will always avoid a major ground accident or incident (e.g. runway incursion, aircraft ground collision). As a consequence, it will be assumed that safety benefits will only be fully delivered if a control function is also implemented.

The strategic objectives of the control function are, in the short term, to improve safety by preventing runway conflicts and collisions and, in the long term, to check the conformance of the taxi route taken by an aircraft with the taxi route assigned.

Next sections describe the potential qualitative benefits available to each category of airport stakeholders. Where relevant, benefits are identified for each of the four benefit areas of Safety Capacity, Efficiency, and the Environment.

4.1.1 ANSP

- **Safety Benefits**

Improved Situation Awareness:

Accidents during taxi phase in Western Europe and North America represent two thirds of the worldwide number of accidents [A-SMGCS implementation in Europe; IFATCA (2003)].The ability to display on a screen the exact picture of the ground traffic provides the ground controller with an accurate traffic situation. This enhances the controller's situational awareness and improves overall ATC safety.

In good weather conditions, surveillance data will be used as an enhancement to visual observation, replacing it when the controller believes that it is appropriate (e.g. controlling traffic at the holding position a long distance from the tower) and for observations which are not directly visible by the ATCO. The data also allows the ground controller to spot vehicles more easily, especially when the taxiway and runway layouts are very intricate.

In reduced visibility conditions, the surveillance service will help the ground and aerodrome controllers to provide the same level of control service as in good weather conditions. While the complexity if aerodrome surface movements increases as visibility decreases, the combination of cooperative sensors will improve situation awareness especially in difficult weather situations. The most significant advantage of surveillance under reduced visibility conditions is that the controller is not dependent on position reports from the pilot (or a primary radar screen that is difficult to interpret). In addition, developed SMGCS based on SMR present some deficiencies (loss of targets, plot clutter due to rain, etc), that A-SMGCS is expected to alleviate.

With A-SMGCS surveillance, the controller has an effective means of control, which allows him/her to get position information of aircraft on the manoeuvring area and which enables him/her to detect any mismatch between issued controller clearance and execution by the pilot. Incidents in conjunction with taxiway confusion turned into accidents, because they remained undetected by the controller. runway incursions can be prevented or at least detected by the controller if surveillance information is available. It is also expected that the ATCO workload by aircraft will be reduced.

A-SMGCS surveillance function benefits include:

- The reduction of aircraft backtracking on a runway without informing air traffic control, when others are cleared to land or take-off;
- A decreasing number of aircraft and airport service vehicles lost on the runways, thus requiring the airport to close down for a time;
- The absence of runway confusion by pilots;
- A significant reduction of runway intrusion as a result of a mistake or a control misunderstanding.

Parameters provided by the surveillance function - such as speed, trajectory, and identification of moving aircraft and vehicles - allow controllers to better anticipate the intentions of ground traffic.

The A-SMGCS control service through detection and alerting function will also improve ATCO situation awareness and augment safety by detecting incursions (runways and taxiways) and infringements caused by aircraft / vehicles, tracking route deviations, detecting any potential mobile conflict and providing solutions. Enhanced anticipation of conflicts is a factor in traffic conflict reduction and in ATC safety improvement.

The combination of routing and guidance services (either ground based or provided by datalink), by providing routing and guidance instructions (visual aid), will enable clear, unambiguous and continuous indications to pilots and vehicle drivers, thus increasing safety.

<u>Provision of a safety net:</u>

With a control service, the provision of automatic warnings when the system detects a runway incursion, a restricted area infringement or any other hazardous event will permit conflicts to be anticipated and avoided, and alert the controller to potentially dangerous situations.

Benefits include the ability to maintain the required separations between moving vehicles and with obstacles, the detection all forms of conflict and their solving (conflict resolution function). Improved anticipation will be obtained through medium-term alerts that can be resolved by modifications in planning. These alerts can be transmitted by the controller in semi-automatic mode or better to the moving vehicle or aircraft concerned in automatic mode.

Quantifiable benefits encompass cost avoidance for aircraft loss, loss of life disruption to aerodrome services and induced cost of investigation.

- **Capacity Benefits**

Low visibility curtails the overall ATM capacity and impedes apron activities. The application of new technologies will help airports maintain their throughput through when visibility is reduced [A-SMGCS implementation in Europe; IFATCA (2003)]. In low visibility conditions, ground control is converted from a visual control process into a procedural control process. This greatly increases controller workload and hinders ATC capacity. A surveillance function will maintain the tactical control capability and hence reduce controller workload under these conditions. An increase of airport capacity in low visibility conditions and at night due will be observed due to continuous application of tactical control.

Benefits from better planning will be realised under all conditions since the labelling of traffic gives the aerodrome controller responsible for the runway a better indication of taxiing traffic.

Benefits will also arise from being able to maximise throughput in conditions where this would not be possible without a surveillance function. The impact in these conditions depends on the complexity of the ground layout (intricacy of airport tracks, taxiways and runways) and on local LVO implementations.

The magnitude of these benefits delivered will depend on the development of suitable procedures. The evolution of the “see and be seen’” principle requires the definition of new operational rules to be applied by ATCOs (pilots, and drivers). However, even if these procedures are not fully developed, the availability of surveillance will increase ATCO's confidence in handling aircraft in low visibility conditions and this increase in confidence should lead to an increase in throughput. Since the procedures that are developed would be compatible with the implementation of MLS or other landing procedures, the use of the surveillance function will help facilitate a reduction in aircraft spacing in low visibility conditions and thus the capacity limitations at the runways.

- **Efficiency Benefits**

Reduction of voice communications:

Automatic position reporting without voice intervention is expected to result in a reduction of ATCOs workload. In addition CPDLC will reduce voice communications which will migrate into a mix of voice and datalink capabilities (voice communications will continue to be used when necessary).

A reduction in the amount of verbal communication can lead to improved controller efficiency and reduce the possibility of communication errors. Especially when the controller does not have visual contact with aircraft, the reduction of the need for verbal communication to determine aircraft position can be significant, participating to reduce controller workload per aircraft.

Improved handling of aircraft:

In some cases, especially during low visibility conditions, the surveillance function allows the ground controller to track aircraft on the manoeuvring area. This increases controllers' awareness of the traffic situation and should allow them to handle aircraft more efficiently, at least in low visibility conditions. This does not automatically mean that the controllers' task load can be significantly increased – complexity of traffic, procedures, and aerodrome layout can impose to keep the traffic at the same level, however, the controller workload related to handling a specific flight should decrease. For instance, surveillance will help both aerodrome & ground controllers to better plan traffic due to their ability view the traffic situation over the whole movement area. Using the Surveillance function will improve the co-ordination between the ground and aerodrome controllers since both controllers will have a common situation awareness on landing and departing aircraft.

Efficient surface flows of aircraft:

Efficient flow of aircraft and optimum arrival and departure streams will be improved by the combination of routing facilities and efficient and integrated departure and arrival management. Overall taxiing times should then be shortened.

The routing service will provide the controller with a most efficient taxi route consisting in route and time information. In manual mode, this route is assigned by the controller who transmits it to the vehicle or aircraft concerned. In automatic mode, this route is assigned directly to the vehicle or aircraft, but is cleared by the controller finally. So as to assign routes correctly and less fault-prone, the routing function shall take into account all the data and constraints involved in the problem and be capable of reacting in real time to any change that may occur. For maximum benefit, the routing function shall not be an additional constraint, but a means of assistance in reducing taxiing times and ground traffic flow improvements.

Better use of the runway capacity:

The control service of an A-SMGCS will allow the controller to better utilise the runway capacity by increasing aircraft throughput. The benefit obtained through the support of an optimised departure and arrival sequence will allow for better planning and more traffic to be handled safely and will participate in reducing controller workload especially during busy situations.

4.1.2 Airline

- **Safety**

Airlines and their customers – the flying public – will have a safer environment on the ground; through better situational awareness; runway and area incursions leading to catastrophic accidents and incidents will be reduced considerably.

.This is especially true in reduced visibility conditions where the aircraft commanders' obligation to see and avoid other aircraft is greatly impaired.

Clearances received from ATCO by voice will be "traceable": either a graphical description of such a clearance or a text format can be used to crosscheck the correct interpretation of a verbally transmitted clearance. Such backup will serve as an additional safety net which does not yet exist in today's cockpits.

- **Efficiency**

As a commercial rule the time period on the ground for a given aircraft must be kept to a minimum: whilst an aircraft is on the ground it is non-productive, no revenues are generated. Airlines have undertaken every effort to enhance their operational processes whilst the individual aircraft has arrived at the gate/stand. A-SMGCS functions will pave the way to equally reduce taxi time thus minimising overall ground times.

For a given demand from the airlines, an increase in available throughput brings about a reduction in total delay. This reduction would be particularly substantial in low visibility conditions during which ATC capacity is reduced. In some cases, it could prevent aircraft from flying in holding patterns and would thus reduce the risk of diversion.

A more seamless operation of aircraft on the ground would be a major advantage. Under specific circumstances, mainly when the ground controller encounters difficulties in establishing visual contact with taxiing aircraft due to darkness, low visibility conditions, hidden areas, etc., the use of a surveillance function could allow an airport to maximise throughput and hence reduce delay.

Where a Service Level Agreement (SLA) has been reached to allow AO (Aircraft Operators) to have an A-SMGCS monitor in the AOs operations room/hub control centre, the AO will be able to monitor the progress of their flights on the airport which will assist in better planning of ground handling resources and management of flights.

4.1.3 Vehicle Driver

- **Safety**

The surveillance function will provide safety benefits to suitably equipped vehicle drivers. Equipped vehicles will be better identified by the controller and can be prevented from entering hazardous or restricted areas, such as taxiways and runways, without authorisation. In addition using the moving map display the vehicle driver's situational awareness will increase, with an increase of safety. In general it can be concluded that A-SMGCS will raise situational awareness for both, controllers, and pilots that will result in a safer airport environment under low visibility conditions.

4.1.4 Passengers

- **Safety, Capacity and Efficiency**

Passengers will directly benefit from a safer and more efficient airport system for obvious reasons:

Increasing the level of Safety will have double effect on passengers; it will reduce life risks and it will raise confidence of passengers in the Aviation environment.

Efficiency of an airport can be directly linked to delays, which are so important for passengers nowadays, as it means no waste of time. Delays reduction will also have other implications related to the quality of life of citizens, to quote a couple of examples: reduction of emissions and fuel burnt if taxi time or time waiting at the departure queue is reduced.

Increase of available capacity associated to A-SMGCS would result in more flights available to cover passenger's needs. Furthermore, arguments mentioned above lead to reduction of costs for airlines and consequently for passengers.

4.1.5 Airport operators

- **Safety**

Increasing the level of safety is always a clear and defined objective of any airport that would raise passengers and airlines satisfaction. As it has been explained above, A-SMGCS will increase safety by reducing the number of accidents and incidents, especially during low visibility conditions.

- **Capacity**

Airport capacity will be increased, especially during low visibility conditions, which means that more aircraft and passengers will be able to fly to and from this airport. More passengers and flights mean higher economical benefit; more passengers would spend more money in the terminal and more flights would mean more airport taxes, etc.

- **Efficiency**

Airport Operators benefit from increased throughput in a similar way to airspace users.

Where an agreement has been reached to allow the Stand and Gate Management authority to have an A-SMGCS monitor in their operations room/cell, the Stand and Gate Management will be able to monitor the progress of their flights on the airport which will assist in better planning of stands (parking areas). The A-SMGCS, together with an increased Collaborative Decision Making process, can also provide accurate and timely data such as landing, take off, in block and off block times.

A more efficient system will imply higher client satisfaction and would enhance fidelity of aircraft operators and a better use of available resources at the airport (that would have an economical benefit).A-SMGCS display would be useful for airport operations units such as

a. Airport Operations Unit

b. Surface Maintenance Unit (sweeping, snow removal)

c. Electrical Maintenance Unit

d. Bird prevention Unit

e. etc.

For all of mentioned, it is helpful to see on a situation display where service vehicles are located, which activities have been completed etc.

As an example of this, Prague Airport uses A-SMGCS at Airport operations Dispatching Room. With A-SMGCS display is now clearly visible if, for example, snow removal on the RWY is close to finish and when the right time for measuring of braking actions will be. Or in case of maintenance works on Movement Area it can be seen when works have been completed and if is the time to go there and put that area into operation. Furthermore it is possible to plan RWY inspection much more efficiently (dispatchers always check arrival and departure table in A-SMGCS and find "gaps" in the traffic as an opportunity for RWY inspection). Nowadays, when LKPR operates at the maximum of its RWY capacity they save up to 45min. of waiting at the holding position of the RWY.

- **Environment**

Efficiency increase associated to the use of A-SMGCS should result in reduction of time waiting at the holding point to depart, time waiting at the stack to initiate the approach, taxi times and in general a reduction of delays, between many others. There is also a direct relation between the delays and the amount of fuel burnt and the emissions, which should be significantly reduced for the general benefit of humanity. A less polluted environment would be the possible way to demonstrate to communities leaving near airports, that airports do care about environment. Getting across this message would decrease resistance and fear from society to further airport developments.

4.1.6 Ground Handling

- **Efficiency**

Where an agreement has been reached to allow GH (Ground Handling) companies to have an A-SMGCS monitor in their operations room, the GH companies will be able to monitor the progress of incoming flights on the airport which will assist in better planning of ground handling resources and equipment.

Following the principle “a chain is only as strong as its weakest link” and considering that ground handling is part of the flight chain, the possibilities offered by A-SMGCS, assisting and supporting a better planning of available resources, will help to achieve a stronger and more efficient airport system.

Clients (aircraft operators) satisfaction will increase with a better quality of the service, due to an optimised planning and management of equipment and resources.

Furthermore, A-SMGCS is great opportunity how to increase fluency of aircraft de-icing. Sometimes de-icing vehicles are not present at the de-icing stand on time and the whole sequence is delayed. With A-SMGCS display, provider of de-icing services is informed about current position of every aircraft and the time when aircraft reaches the de-icing stand can be predicted.

- **Capacity**

In case that Ground Handling Service was one of the constraints to airport capacity, an improvement of the planning capabilities and management of resources (available through A-SMGCS) could release latent capacity.

- **Environment**

The more efficient a system is the less energy is wasted.

4.1.7 Airport Community

- **Safety**

Reduction of losses in terms of human lives.
Reduction of losses in terms of local airport equipment, often financed by airport community.

- **Capacity**

Increased capacity and in general a more developed aviation environment has an important effect on the economical development of a region. More capacity would provide directly or indirectly more jobs, increase of tourism, more visitors using local hotels, restaurants and related businesses.

- **Efficiency and Environment**

Efficiency increase associated to the use of A-SMGCS should result in reduction of time waiting at the holding point to depart, time waiting at the stack to initiate the approach, taxi times and in general a reduction of delays, between many others. There is also a direct relation between the previous and the amount of fuel burnt and the emissions, which should be significantly reduced for the general benefit of the airport community.

Main achievements would be: a less polluted environment and a clearer idea of how important environment is for airports.

4.1.8 Aeronautics Industry

The benefits for the aeronautics industry arise from the purchase of the equipment required to implement the application.

Aeronautics industry would benefit from any technological development of an airport. Developments required for the implementation of A-SMGCS would have a significant impact on employment and manufacturing infrastructure.

The investment of airports in A-SMGCS technology will pay back research and development costs that will therefore be available to continue with research in the same or in other areas.

Implementation of A-SMGCS would make stronger the European industry in the international aeronautics market.

4.2 Anticipated Constraints

The purpose of this section is to identify the costs incurred by different stakeholders in implementing A-SMGCS.

4.2.1 ANSP

Depending on how the airport is organised, the cost of acquiring and operating ground based equipment, and installing and integrating the surveillance and control functions could be incurred by an ANSP or an Airport Operator.

A system providing co-operative surveillance will be required, and targets need to be equipped with means of communicating information on position and identity. It is also essential that some means of surveillance is available to enable the system to detect non co-operative targets including obstacles.

The main constraints associated to the implementation of A-SMGCS are cost related.

Some examples of direct bearers of the cost are:

- the acquisition and operation of ground based equipment,
- the installation and integration of surveillance and control functions,
- the development of procedures and adaptation to local airport needs,
- testing and validation
- training
- maintenance

Depending on the future evolutions of A-SMGCS implementations on a given airport, there may also be restrictions on the choice of the industry, which will provide the A-SMGCS extensions. Some implementations may require to systematically calling on the same providers, in order to ensure compatibility with the existing A-SMGCS. This may have a negative impact on competition, and on a long term, on cost effectiveness.

In these difficult moments for the aviation environment the cost/benefit ratio has to be investigated. Any investment needs to be justified in order to be able to survive in such a competitive market. As a result of this, strong arguments in support of A-SMGCS implementation need to be provided. A few examples of parameters that could serve to evaluate the cost benefit ratio are:

- Impact of low visibility conditions on safety, efficiency, capacity, and environment without A-SMGCS
- Number of days with VIS 1, VIS 2, VIS3, VIS 4 conditions
- Number of movements per day, month, year
- Number of passengers per day, month, year

- Estimated capacity increase
- Estimated efficiency increase (reduction of delays, taxi time, time waiting at holding to depart, etc)
- Estimated environmental benefit.

4.2.2 Airline

4.2.2.1 Cost of on-board equipment

Some aircraft are already equipped with Mode-S technology, as it has been developed for airborne surveillance. Mode-S Elementary Surveillance is a mandatory requirement on 31 March 2005 for all aircraft flying IFR as GAT in designated airspace, and on 31 March 2008, subject to individual state agreements, for all aircraft flying VFR. Since this covers the vast majority of aircraft using the airports that are likely to adopt the ground-based surveillance and control functions, the cost of equipping aircraft is assumed to be zero.

To enhance further functionalities of A-SMGCS airlines depend largely on the individual aircraft manufacturer: As soon as a manufacturer offers a new aircraft type new technologies and functions are incorporated as a standard or an option at extra cost. It is then the choice of the respective airline to choose from respective options offered.

It is believed that manufacturers will offer basic advanced A-SMGCS functionalities for new aircraft types as a standard. Retrofits for existing types/models on an individual basis are cost/time intensive mostly lacking a valid business case and thus not realistic for an individual airline. Besides procurement cost for the additional/upgraded electronic equipment the required downtime for their aircraft out of revenue service is a major cost factor.

It is up to the aircraft manufacturers to decide if an upgrade of the electronic suit of in service types/models is appropriate, e.g. midway of the life cycle of such type/model. Airlines then will have the choice to upgrade their tail numbers depending on the individual business case.

4.2.2.2 False and nuisance warnings

Like with other highly interdependent on-board functions every effort must be taken to avoid false and sometimes nuisance warnings. It must be kept in mind that any warning/alert/information generated in relation to A-SMGCS functionalities will distract the flight crews' attention to a certain extent.

Lessons learnt when similar complex safety critical functions have been incorporated mandate a careful planned phased implementation process one by one.

Under all circumstances functions that are failure/nuisance prone are a detriment to safety and more important to efficiency: Handling of a warning. e.g. generated by the Surface Movement Alerting will immediately slow down taxi speed or stop the aircraft concerned until the relevance of that warning can be verified.

In this context the validity of the on-board database in relation to short term NOTAMS is thought to be a major concern.

4.2.3 Vehicle Driver

The main constraints associated to the implementation of A-SMGCS are, as in the previous cases, cost related.

Some examples of direct bearers of the cost are:

- the acquisition of equipment,
- the installation and integration of surveillance and control functions,
- the development of procedures and adaptation to local airport needs,

- testing and validation
- training
- maintenance

As said in the previous cases, nowadays, any investment needs to be justified operationally and economically.

4.3 Associated Human Factors

4.3.1 Human Factors Issues Identification

This section provides the human factor issues considered essential for the safe and coherent operation of the EMMA services.

The Human Factors identified in this section are extracted from the EUROCONTROL "Human Factors Plan for A-SMGCS Levels 1 & 2 – version 1.0 released issue 14/01/2004" document.

Because the task context is so critical in Human Factors, it is often necessary to research the area prior to conducting the Human Factors Issues Analysis study.

A default checklist is shown on next page, developed by EUROCONTROL in the "Human Factors Case: Guidance for Human Factors Integration – version 1.0 released issue 16/04/2004").

Human Factors Area	Item
1. Human-Machine Interface and Working Environment	Input devices, visual displays, information requirements, alarm handling, console/working area, HMI usability, user requirements, health risks, fatigue, distraction and concentration, noise, lighting, temperature/humidity/air quality, workplace arrangement, workplace accommodation.
2. Organisation and Staffing	Staff requirements, manpower availability, ATCO profile/selection criteria, job attractiveness, ageing, shift organisation.
3. Training and Development	Training needs, performance/competence standards, training content, training methods and media, negative transfer of training, trainer role/responsibilities/competency, transition from classroom to OJT, emergency/unusual situation training, testing of training effectiveness, negative effects on operational task performance.
4. Procedures, Roles and Responsibilities	Allocation of function, involvement, workload, trust/confidence, skill degradation, procedure format and positioning, procedure structure, procedure content, procedure realism.
5.Teams and Communication	Team structures/dynamics/relations, (inter-) team co-ordination, position handover processes, communication workload, phraseology, national language differences, changes in communication methods, interference effects and information content.
6. Recovery from Failures	Human error potential, error prevention/detection/recovery, detection of and recovery from system failures.

From this list, the following has been selected to specifically address the A-SMGCS issues:

Procedures, Roles and Responsibilities:

- Trust and confidence, important for acceptance, linked to reliability;
- Continuous involvement of operational people, inclusion of non ATC population (e.g. Apron management);
- Workload (hypothesis: workload decrease);
- Skill diversification, increased use of surveillance data, head down/head up time;
- Procedure format and structure should reflect the way people act or try to act today. Current/existing and new procedures;
- ATC procedure applicability and relevance. Safe, useful, up to date.

Human Machine Interaction

- Generic advice for HMI and workplace accommodation such as input devices, visual displays / lay-out, and console area;
- Default settings;
- Intuitive interface;
- Limited settings for colours, fonts, number of windows;
- Consoles/displays shouldn't obstruct controllers view
- Ergonomics (distances, size of screens);
- Local requirements may add specifics;
- (False) alarm handling;
- Integration with other systems (electronic flight strips, runway incursion monitoring);
- Specifics of tower lighting;
- Health/fatigue: head up/down and eye-muscle (colours, brightness);
- Impacts of new displays etc. on temperature/humidity/air quality.

Training and Development

- Identification of additional training needs, content and methods - including recurrent training - for Aerodrome Control Surveillance Ratings or qualification. (Skill diversification, Head up Head down issue, understanding of how multilateration works);
- Definition of additional competence standards;
- Negative transfer of training;
- Trainer role and competency, as for all new tools/developments;
- Transition - changes to pilot and driver communications, procedures including transponders;
- Recovery and contingency training.

Teams and Communication

- Team structures/dynamics, better shared SA (e.g. CDG: monitors for the TMA controller) will reduce need for co-ordination;
- Hand over, (new) tool specific, visual support will make hand over 'easier';
- Potential decrease of communication workload;

- Changes in communication methods, e.g. silent hand over, less need for co-ordination, changing feedback loops;
- Team differences (e.g. in use of tools) and transfer of individuals;

4.3.2 Controllers' Considerations on Human Factors

Some human factors issues relate to the introduction of A-SMGCS as they follow from the use of a ground display with labelled traffic where previously outside view (in good visibility) and a radar screen or pilot reports (in bad visibility):

- General acceptability issues;
- Controllers' situational awareness;
- Identification of aircraft and vehicles at the airport;
- Hand-over procedures in the tower;
- Controllers' head-down times;
- Recovery from lost targets and label swaps.
- Issues linked to the introduction of a Runway Incursion Alerting System

4.3.2.1 Acceptability issues

The new tool provided to the controller is a ground display which shows the airport layout with all aircraft and vehicles in the movement area. The positions of the aircraft and vehicles are indicated by a target symbol, and the target symbol will be clearly identified by an aircraft/vehicle label.

It is assumed that ergonomic principles for the design of such displays will be followed, and controllers have been adequately trained to use the surveillance display (including the provision of an adequate working method, and means for recovery from system failure).

Controllers' acceptability about introduction of new technology and associated procedures is a major issue. Acceptance will increase if her/his ideas are taken on board in a very early stage and if his concerns are taken serious. Some of the major ones are:

Any new equipment and more screens cause ergonomic problems, obstruct the free view to the manoeuvring area. In addition it may lead to an overflow of information resulting to increased workload and higher stress level;

Decreased head-up time, increased head-down time – is definitively a burning issue which results from a growing number of controller tools and screens in the tower.

Proper procedure design and controllers' training should be guaranteed – an aspect, which is often handled with low priority or even forgotten (one handbook or manual per controller replaces the entire training)

If workload increases, the staffing in the tower should be adjusted. This is a very critical statement. Employers (and customers) are aiming for the opposite effect – they want to minimise costs for personnel, technology is intended to replace part of the humans in the process.

Safety should never be compromised, it always has to remain the number one priority and should not be overwritten by capacity or "controller productivity".

Depending on the specific airport, controller functions can comprise clearance delivery and start-up control, Ground (or Apron) Control, and aerodrome Control. For the analyses below, the functions of the ground controller (responsible for taxiing aircraft on the airport) and the Runway Controller (responsible for take-off and landing clearances) are considered.

For the analysis on the effect of A-SMGCS surveillance on the controller task, assumptions on the baseline condition (i.e., non A-SMGCS) need to be made. It is assumed that the Ground Controller works on the basis of the outside view and paper flight strips in good visibility. In low visibility, the Ground Controller works on the basis of a primary radar screen for ground movements (without vehicle identifiers) and paper flight strips. For the aerodrome Controller, the same holds for aircraft on the ground. The aerodrome Controller is also provided with an Approach/Departure Radar (with aircraft identifiers) in order to monitor departing and approaching aircraft.

It is assumed that controllers would be requested to work primarily on the basis of outside view (using the ground display as additional tool) in good visibility. We expect that future improvement of the surveillance function, will allow purely ASMGCS control in LVO conditions. Because controllers will monitor ground movements mainly on the basis of the outside view, the analysis below is in large parts restricted to low visibility conditions. If effects are also expected for good visibility conditions, this will be explicitly mentioned.

4.3.2.2 Controllers' situational awareness

Situation awareness is the continuous extraction of environmental information, the integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events" [Dominguez et al., 1994].

Situational Awareness refers to "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" [Endsley, 1995]. For the controllers in the tower (i.e., Ground and aerodrome Controller), situational awareness is given if the controller is aware of the current position, the (clearance) status, and the intentions (e.g. taxi route and gate for inbound traffic, taxi route and RWY and SID for outbound traffic) of an aircraft under control or directly affecting aircraft under control.

In low visibility conditions, ground and aerodrome controllers in a non A-SMGCS setting use a primary radar screen for monitoring the traffic situation at the airport. On the primary radar, no aircraft or vehicle identifiers are provided. With A-SMGCS surveillance a ground display will be provided that displays the position and identifier of all traffic on the airport. For this reason, the introduction of a ground radar screen is expected to substantially increase situational awareness in low visibility. The probability of incomplete or incorrect knowledge of the traffic situation on the airport in low visibility, on the other hand, should be significantly reduced.

For good visibility conditions, it is assumed that the benefit of A-SMGCS Surveillance is less prominent. Here, controllers would still work primarily on the basis of outside view. However, in case of several aircraft of the same airline behind each other, or a mismatch between the operator of a flight and aircraft (e.g. KLM aircraft operated by Northwest), the identification of an aircraft might be difficult even in good visibility. In this case, the ground display could offer additional information to reduce the uncertainty as to what aircraft corresponds to which flight number.

So far the benefits discussed are limited to those aspects of situational awareness that refer to the representation of the current traffic situation. With respect to the projection of the aircraft status into the near future, a further benefit would be achieved under two conditions: (a) if inbound and outbound traffic are displayed in an easily distinguishable manner (e.g. in different colours), and (b) if the displayed aircraft labels contained the gate (for inbound traffic) or the RWY (for outbound traffic).

It could be argued that controllers usually manage to have a good situational awareness in low visibility conditions even if they are not provided with an A-SMGCS surveillance function (ground display with labelled traffic). However, the cognitive processes needed to build the situational awareness are much more effortful if no ground display with labelled traffic is provided.

However a large part of errors attributed to human operators actually accrue from errors in their situational awareness. The most important source of operational errors (Endsley and Rogers) made by the controllers resulted in failures to monitor key situation parameters due to distractions by other pertinent tasks. The taxonomy of situation awareness issues includes:

Failure to correctly perceive information due to:

- data non available,
- data hard to discriminate or detect (poor runway markings, inadequate lighting, noise problems in the cockpit, obstructions blocking the controller's view),
- failure to monitor or observe data (high task load, omissions, distractions imposed by other relevant tasks),
- misperception of data (misunderstandings, influence of prior expectations),
- memory loss (high workload and distractions);
- Failure to correctly integrate or comprehend information, due to the lack of a good mental model (most frequently associated with an automated system), use of incorrect mental model (leading to misinterpretation of the situation), over reliance on system;
- Failure to project future actions or state of the system (mental projection is a demanding task).

4.3.2.3 Identification of aircraft and vehicles at the airport

The provision of ground labels renders the identification of radar targets on the screen much easier in comparison to a primary radar picture without aircraft labels. This is due to the fact that every radar target will be foreseen with a unique identifier (i.e., the aircraft or vehicle label). By attaching a unique identifier to the radar target, the different targets on the screen become more distinct and uncertainty is minimised. Therefore, the misidentification of a radar target – which is possible with a primary radar display without labels – is significantly reduced.

However, the introduction of a ground display does not only have a positive effect on the reliability of the target identification, but also on the speed with which this target identification is performed. Response times in a (sequential) visual search task depend on the *similarity* of the set of stimuli and the *size of the search set* [e.g. Treisman & Gelade, 1980]. The search set is the set of radar targets that need to be scanned in order to identify a specific target. *Similarity* of the stimuli is decreased by adding a target label to the otherwise indistinguishable radar dots. If inbound aircraft, outbound aircraft and vehicles are displayed in such a way that they are immediately distinguishable (for instance, by using different colours or shapes of target labels), the search set can also be reduced. This means that, in case an inbound aircraft needs to be identified on the ground display, the controller can just scan the labels of inbound traffic.

Taken together, the introduction of a ground display with traffic labels (i.e. A-SMGCS level 1) is expected to result in shorter search times and a more reliable identification of aircraft or a vehicle that calls in on the frequency in comparison to a non A-SMGCS environment with primary radar only.

4.3.2.4 Hand-over procedures in the tower

Hand-over procedures are usually carried out in such a way that the controller on the next position immediately knows which paper strip belongs to which aircraft or – in low visibility – to which radar target. Therefore, the need for searching through all targets on the screen in case an aircraft calls in is usually reduced.

Specific hand-over procedures might vary between airports; however, on a busy airport and low visibility, a hand-over procedure from one position to the next would typically be as follows: The Start-up Controller points to a specific target on the radar screen when handing over the corresponding paper flight strip to the Ground Controller. The same holds for handovers from the Ground Controller to the aerodrome Controller and vice versa. This means that the next controller is informed as to what radar target corresponds to which aircraft. The controller's task is then to retain this association between aircraft and radar target in memory and continuously update the mental representation corresponding to the evolution of the traffic situation at the airport. Consequently, searching on the radar screen in order to identify a specific aircraft is not one of the core tasks of Ground or aerodrome Controller.

However, a visual search through the set of all aircraft is required whenever the controller did not manage to keep track of all changes in the traffic situation and maintain an awareness of the traffic situation at the airport. In order to regain awareness of the traffic situation, the controller needs to scan the targets on the primary radar and the paper flight strips again. Furthermore, the controller needs to establish the link between radar targets and paper flight strips.

With A-SMGCS Surveillance, the hand-over procedures from one position to the next in low visibility can be simplified. It will not be longer necessary to communicate to the next controller which radar target belongs to which strip. Because of the labelled ground display, the probability of loosing track of the traffic situation will be substantially decreased, and recovery from this situation will become much easier.

4.3.2.5 Controllers' Head-Down time

Head-down time relates to the time an operator (a pilot, driver, or controller) spends on monitoring an assistant tool that is placed under the primary visual field. This primary visual field is often the outside view. In the literature, a problem is discussed which is referred to as the head-down problem, e.g. the inability of an operator to optimally divide attention between the primary visual and the assistant tool [*cf. Hilburn, 2004*]. This lack of distributing attention adequately might yield a situation in which the operator misses a critical event on the primary visual field because his or her attention is directed to the assistant tool.

For the introduction of A-SMGCS Surveillance – in which the Ground and aerodrome Controller will be provided with a ground display with labelled traffic – the head-down problem would manifest as follows: the controller has to allocate attention to the Ground Display and, has, for this reason, less capacity – in terms of time or attention - to monitor the traffic situation through the tower window. As a consequence, the controller might miss crucial information on the airport.

There are a couple of reasons that indicate that, at least for A-SMGCS surveillance, the head-down problem for the controller is qualitatively different and less problematic than the head-down problem in other domains (such a driving a vehicle).

First, current airport procedures already dictate that in bad visibility, control is performed on the basis of the outside view and flight strips, but on the basis of the radar screen and paper strips. These procedures do not have to change with the introduction of A-SMGCS surveillance. The only difference is that the primary radar screen is replaced by a much more user-friendly ground display with labelled traffic.

Second, head-down time is not negative per se. If the outside view is such that it does not provide the adequate physical stimuli to control ground movements, whereas the head-down display does, then the use of the head-down display is to be recommended.

Third, at least for the Ground Controller, the information obtained through the analysis of the outside view should be fairly similar to the information displayed on the ground display. This refers to the position of aircraft and vehicles on the airport as well as to the direction and movement of them[31].

Nevertheless, the problem of head-down time to address A-SMGCS surveillance should not be neglected. Even if the operational procedures pertaining to the use of outside view vs. head-down display in low and good visibility are not changed, the controller might develop a tendency to use the ground display even in good visibility. Furthermore, at least for the aerodrome Controller (whose task it is to monitor the safe conduct of take-offs and landings) there is relevant information that is only available by looking out of the tower window, for instance:

- Any signs of abnormal aircraft performance (e.g., smoke from the engine, burst tyres) or abnormal aircraft operation (e.g. late touchdown),
- Irregularities in the airport infrastructure (e.g., RWY lightning)

[31] It could be argued, though, that movement of an aircraft can be detected quicker and more easily by looking out of the window.

- Rapid changes in weather.

For this reason, measures need to be taken to prevent the Ground controller and especially the aerodrome controller from overly using the ground display. These measures primarily involve the definition of appropriate operational procedures, but should also comprise training on how to optimally allocate attention to the various sources of information in the tower.

4.3.2.6 Recovery from lost labels and label swaps

With respect to the ground display with traffic labels, two kinds of partial malfunction can be distinguished:

- lost labels on the display, and
- label swaps.

Note: A complete failure of the Surveillance function as well as a lost radar targets will not be addressed in the present analysis, as these situations are not assumed to qualitatively differ from a failure of the primary radar or a lost radar target.

The likelihood of lost labels and label swaps has to be determined on the basis of a technical analysis. The predicted frequency of these events influences both the considerations that need to be given to this problem as well as the controller's response to partial malfunction.

Lost labels. A lost label refers to a situation in which a radar target is provided with a target label, although the surveillance function (and thus the ground display) is generally working. It could be argued that a situation in which a target on the screen is not provided with a label does not differ from a situation in which no a target does not have a label because the primary radar does not support a label display. This claim, however, does not appear to be valid:

First, a controller working with labelled ground traffic will have adapted his or her working methods to this tool. In low visibility conditions, for instance, he or she might be less careful to build a mental representation of the traffic situation (and retain this representation in memory) as the ground display usually provides an external memory aid.

Second, the radar target without a label among a set of labelled targets is less salient and is more likely to be overlooked. This problem can be pronounced if the radar target of the unlabelled aircraft or vehicle is hidden by the label of another aircraft or vehicle.

Since it is assumed that, in good visibility, aircraft are primarily controlled on the basis of the outside view, the impact of lost targets would be restricted to low visibility. Even in low visibility, a lost aircraft label should not yield a break-down in controller performance. First, it is much easier to establish a link between an (electronic) flight strip and a specific target if only one target does not have a label and all other targets are labelled. Second, as there is an (electronic) flight strip for every aircraft under control, it is unlikely that the controller will forget about an aircraft which radar target is difficult to see or hidden by another label. Vehicles, on the other hand, can be probably overlooked more easily.

Label swaps. A label swap refers to a situation in which a label is attached to a radar target on the screen to which is does not belong. A label swap can yield to a misrepresentation of the traffic situation at the airport, because the controller has wrong information about the type of traffic on a specific position. As a consequence, the controller can issue a clearance to the wrong aircraft, which could yield a safety-critical situation.

Negative consequences of a label swap are expected to be restricted to low visibility. In good visibility, control of traffic should be primarily based on the outside view (rather than the ground display). Even if the label swap on the ground display confuses the controller, the identity of an aircraft or vehicle can be established by looking out of the window. There might be problems, though, if the label swap affects aircraft of the same type and airline.

In low visibility, a label swap can have more severe consequences, as there is no physical cue that immediately triggers the detection of the label swap. If the controller possessed a good representation of the traffic situation on the airport prior to the swap, it is reasonable to assume that the label swap will be detected by the controller. However, it cannot be excluded that the label swap remains undetected and yields a wrong representation of the traffic situation. In order to analyse the possible consequences of a label swap in more detail, it needs to be known how likely label swaps are, and what kind of condition need to be met for a label swap to occur.

In a training perspective, controllers need to be made aware of the possibility of label swaps and should be trained on how to diagnose and recover from such label swaps.

4.3.2.7 Reliability of the alerting functions: false alerts and missed incursions

The aim of automated warning and alert devices – such as short-term conflict alerts or runway incursion alerts – is to detect a safety-critical event (i.e., a conflict between two aircraft) among the set of all events. Depending on whether a safety-critical event is present or not, and the automated system issues an alert or not, four possible situations can be distinguished: a correct detection of a conflict situation (hit), no detection in the absence of a conflict (correct rejection), a false detection of a conflict (false alarm), and a failure to detect a conflict (miss).

Most automated warning and alert devices are constructed with a bias to prevent misses, as the consequences of a miss can be catastrophic. Because of a trade-off between misses and false alerts and a low base rate of conflict events, attempts to minimise the number of misses result in high false alarm rates. However, if an automatic warning device issues too many false alerts, the human operator's sensitivity towards the alert decreases [*e.g., Koelega, Brinkman, & Bergman, 1986*]. In other words, the operator develops a tendency towards ignoring the alert. Parasuraman and Riley [*1997*] label this phenomenon "disuse of automation": a neglect of automation, which is commonly caused by falsely issued alerts.

What has been observed for other automated warning and alert devices may also hold for the runway incursion alerting system: in case of a substantial amount of false alerts, the controller can develop distrust in the system, which can manifests itself in a lack of response to the alarm. In case of a "hit", that is, a correct detection of a runway incursion, a failure to respond to this false alarm may severely compromise safety.

In order to minimise the problem, it is important that the criterion for detecting a runway incursion is chosen carefully.

Furthermore, controllers should be trained in such a way that they possess a global understanding of the algorithm that underlies the runway incursion alert. In this way, the controller can understand why the system issues a false alarm in a certain situation. Also, the controller can understand why the system might fail to detect a safety-critical situation. In other words, the controller should become aware of the restrictions of the runway incursion alerting system. Knowing the system restrictions helps to prevent over-reliance and fosters an adequate level of trust in the automated tool.

Although there is ample evidence that false alarms negatively affect an operator's sensitivity, there is also evidence that - even with a decreased sensitivity - the operator's performance is better with an alerting system (that also issues false alerts) than without an alerting system [*Lehto, Papastavrou, Ranney, Simmons, 2000*].

4.3.2.8 Human Factors linked to data link use

Datalink may be an effective means to reduce radio congestion and may reduce errors such as readback and hearback errors [*Burki-Cohen, An analysis of tower (ground) controller-pilot voice communications, 1995*].

In particular the possibility to give/receive start-up, push-back and taxi clearances via data link is expected to participate in reducing the voice channel congestion as well as enhancing safety[32].

At the same time however, what impact datalink may have on pilot procedures, and pilot-ATC communications during surface operations remains uncertain. For example, en-route studies have revealed that pilots are slower to respond to datalink than voice commands [(Kerns K). *Data link communication between controllers and pilots: A review and synthesis of the simulation literature*; (Mackintosh), *Designing procedures for controller-pilot datalink communication: Effects of textual datalink on information transfer*]. This may have important implications for surface operations as dynamic routing, holding instructions, and expedited runway crossings are frequent.

In addition, there exists resistance towards the use of datalink in the busy terminal area and for non-routine transmissions [(Kerns K). *Data link communication between controllers and pilots: A review and synthesis of the simulation literature;* (Kerns K), *Human factors in air traffic control/flight deck integration: implications of data-link simulation research* (1999)]. At current the use of datalink for dealing with ground clearances, while aircraft is moving on the ground, is a strong ATCOs' concern which should be investigated during EMMA 2 validation.

<u>Mixed Media environment issues</u>

Data link is expected to reduce voice communications which may migrate into a mix of voice and datalink capabilities. However relevant research that may illustrate some potential issues around a mixed media environment, found that the time interval between messages impacts both voice and textual data link communication. It longer overall acknowledgement times are revealed for both voice and data link when a short interval between messages is observed. Additionally, voice and data link communications have different procedural constraints.

One main constraint is the ability to respond to the message. Because voice is more temporal and often more salient compared to visual modality, a voice clearance may draw a more immediate response. In contrast, a suggested benefit of data link is its flexible access where the pilot can manage the communication task around other flight duties.

Combining the data link and voice media in a mixed environment may alter their characteristics in a way that does not maintain the advantages of each medium separately. To examine whether there may be an impact in switching between voice and data link communication due to the change in modality and communication procedures, the researchers examined the perspective of voice and data link communication in both single medium and mixed media environments. The interval between air traffic control messages was also varied to look at the influence of time pressure in voice, data link, and mixed ATC environments. Results from simulation [(Sandy Lozito), *The Impact of Voice, Data Link, and Mixed Air Traffic Control Environments on Flight Deck Procedures*] indicate that voice transaction times are longer in the mixed than in the single medium environment:

Time pressure that results from short intervals between messages increase data link transaction times in both single medium data link and mixed data link-voice environments.

However, message interval influenced voice communication only in case of a mixed environment when a voice clearance closely follows a data link message.

Closely spaced messages increase the number of requests for clarification for voice messages and review log use for data link messages

Note: The statement that a mixed voice/datalink control mode is not possible from an ATCO's point of view is questionable, e.g. Link 2000+ trials do allow a mixed mode for non time critical control issues.

[32] D-TAXI trials (AIDA project (2005-2006)) will address start-up, pushback and routine taxi messages. The initial taxi route transmitted after pushback via data link in text format without voice read-back (in the test phase there is a voice read-back because of safety reason required by the CAA).

Summary

Thus several Human Factors challenges can be raised facing data link implementation which should be investigated during EMMA 2 validation.

a) controllers will be expected to handle both data link and non-data link-equipped aircraft. As initial implementation of data link for supporting ground clearances function will result in varying degrees of data link and voice communications, mixed mode communication should not be present in high workload phases of flight.

b) another critical issue encompasses the head down time—the time it will take controllers and pilots to compose, send, read, or respond to data link messages and the additional workload induced by entering data. Especially the addition time the crew might spent heads down looking inside the cockpit is a major situational awareness concern.

c) other human factors issues encompass:

- system operability issues (system location, crew alerting, display/message format, input/output), and
- system implementation issues (situation awareness, clearance negotiation, mixed communication between voice and data link).

4.3.3 Flight Crews' Considerations on Human Factors

4.3.3.1 Acceptability issues

With respect to acceptability of A-SMGCS services to flight crews, considerable effort is needed; as with ATCO's; flight crews will have to be convinced by validation and field tests in a routine environment that such services bring significant benefits. It is recommended to offer representatives from flight crew organisations participation from the very beginning of such field trials.

4.3.3.2 Cockpit Alerting Systems issues

The pilot detection of runway incursions based on ground traffic display – which seems good enough to address the majority of runway incursions – requires close runway monitoring on departure roll and short final approach. The induced attention demand and workload, the probability of human error justify the interest for automatic onboard detection of runway incursions.

The roles of cockpit alerting system have expanded that can be problematic in terms of operational safety or obstruct the pilot from having cognitive involvement in resolving hazards.

Non-zero probability of missed detection and false alarms are inherently associated with automated detection schemes.

missed detections: for preventing high-cost missed detections, the alerting threshold is often set at a value which has extremely few missed detections; this often results in a high false alarm rate and pilots may consider them as a nuisance. Some other human factors may be considered, such as the non anticipation of the range of conditions that may cause false alarms or underestimation of the true cost of a false alarm

false alarms: Thus false alarms will require crew allocation of attention to situations that would ordinarily not demand it. At best, it is annoying but at worst, false alarms can distract the crew from real hazards. False or nuisance warning(s) will greatly increase the crew workload thus leading to slow taxi speed or even stop the aircraft until the relevance of such a warning can be assessed. An unacceptable rate of false and /or nuisance warnings generated will be a detriment to safety and efficiency. If over reliance on advance technology is a threat to flying, under reliance is also a major human factor issue, as pilots may tend to disregard real warnings since they have faced many false alarms before. In occurrence of multiple alerts possibilities, cases might occur when alerts will overload the pilot, leading sometimes to silence some types of alerts. The choice to disable the some types of alerts or the system - rendering it useless – would then severely impact safety.

Other human factors encompass their interface opacity into cockpit alerting systems functioning, authoritative aspects which prone to under and over reliance and inherently raise conflicts between the authority and responsibility of the pilot.

Training will be essential in making crew aware of these different human factors issues.

4.3.3.3 Over reliance on automation

While automation is expected to reduce stress and fatigue, over-reliance on it can lead to complacency and associated safety issues. A few studies have pointed out that over reliance behaviours are particularly true with less experienced pilots who may feel more comfortable with automation. Over reliance may result in reducing situation awareness and the ability for pilots to intervene during an emergency. This problem can be significantly reduced by training and operational procedures that command decreased reliance on automation and regular data cross-checking.

4.3.3.4 Electronic Moving Map issues

Cockpit moving map displays are a new equipment to improve flight crews' situational awareness on the airport surface. As flight crews currently use paper maps to navigate on the airport surface, disorientation situations may lead to runway incursions. The EMM (Electronic Moving Map) is expected to show the correct taxi route, thus decreasing mistakes and errors, reducing loss of situational awareness that is thought to be a common cause of flight crew deviations and runway incursions.
If both advanced cockpit technologies such as HUD (Head Up Display) and EMM (Electronic Moving Map) are designed with the primary purpose of aiding navigation, the Electronic Moving Map (EMM) is presented as a head-down display in the cockpit.
Human Factors challenges regarding EMM encompass cockpit working environment which doesn't have room for a keyboard or mouse and the display size and head-down time issues.

4.3.3.5 Situation Awareness issues

<u>Scanning head-down and viewing head-up issues:</u>

Flight crews must maintain a high level of situation awareness during all phases of flight (including surface movement) in order to navigate safely. This maintenance of situation awareness comes from two sources: the cockpit displays and the out-the-window environment.

Depending on meteorological conditions, the out-the-window environment will be scanned for ground-based traffic to identify critical runway characteristics at decision height, and to determine the absence of a runway or taxiway incursion. In low visibility conditions, the out-the-window environment may be represented through head-up symbology.

A serious impediment to the maintenance of situation awareness, and therefore, safety, occurs when the flight crew cannot efficiently process these two information sources.

<u>Specific head-up issues:</u>

The main feature of the HUD is that it is located above the instrument panel, allowing the flight crew to simultaneously view the out-the-window scene and the superimposed symbology, without refocusing the eyes or making large eye-scan movements. The major advantage is that the flight crew member doesn't need to look down to obtain information. He can keep his eyes straightforward. The 'head-up-display' projects the most important data in front of the windshield. The projection is focused at infinity so the flight crew member does not have to accommodate his eyes to read this information in detail. The direct environmental contact is maintained. Therefore, the HUD-display offers possibilities to enhance flight safety. However, the information presented can mask events and objects outside of the flight crew's cockpits by overlapping imagery.

HUDs present information to an operator using a specific symbology which is superimposed on the outside view. In the aviation domain, if HUD has proven to be superior to conventional instrument panel displays, the real benefit results in minimisation of scan time; associated human factors to be considered encompass cognitive tunnelling, defined as the inefficient joint processing of superimposed HUD symbology and the window-out scene.

It is widely assumed that HUDs improve situational awareness compared to conventional head-down cockpits by allowing simultaneous processing of information in HUD and world domains. However visual attention studies have shown that, when flight crews are processing information in one domain, simultaneous processing of information in the other may reveal to be very difficult.

An important issue is whether useful and effective synthetic vision displays are usable in aircraft that have limited size display spaces. Human-centred design should allow human flexibility that is required to be exploited through the presentation of natural information; the method of information acquisition by the pilot should be similar to that experienced by looking out the window. The visibility-based solution should make every flight the equivalent of a clear daylight operation (limited visibility is the single greatest contributing factor in many fatal airline accidents worldwide (Boeing, 1996)).

A few research studies suggest that the HUD symbology should be put away from the out-the window path which has to be followed. More precisely, HUD symbology should be placed at least 8 degrees from the out-of window scene information.

Fixed-location HUD symbology appears to lead to attention tunnelling, which reduces the flight crews ability to maintain awareness of instrument information and information in the far visual scene (Foyle, Sanford & McCann, 1991). With the conventional head-down configuration, attention tunnelling may be disrupted by the eye and head movements necessary to scan back and forth between the panel display and the far visual scene, so joint awareness is improved (Weintraub, Haines & Randle, 1984; Sanford, Foyle, McCann, & Jordan, 1993).

Thus "Scene-linked" HUD symbology should be preferred, where symbols are drawn and move as virtual objects in the out-the-window scene. As the aircraft moves through the world, the scene-linked symbols undergo the same visual transformations as real objects. There are no differential motion cues to cause the visual system to interpret the virtual symbols as separate from the world. In the absence of these cues, attention tunnelling should be prevented, enhancing the ability to process scene-linked HUD symbology in parallel with real-world information.

4.3.3.6 Information Overload & Visual Display Issue

An overload of information, which has to be perceived visually, can lead to confusion and distraction from the information perception demanded to accomplish a task. Likewise, different events have different information values. Thus, it’s worth researching which kinds of information have to be conveyed.

To consider the cognitive capabilities of the flight crew a feature analysis should be undertaken. The stimulus of the outside world has an impact on the cognitive process of the human brain. To increase the efficiency of this process the information presented by the cockpit interface is the vulnerable aspect.

Visual displays should be arranged in a way to reduce information access costs. Displays and panels must be scanned frequently and searched for relevant information.

The reaction time can also be a crucial issue. Within an emergency situation it is important to react as quickly as possible. To support the monitoring and emergency reaction task the principles based on attention should be applied here. Thus, besides minimizing the information access costs, the proximity, and multiple recourses principles are appropriate.

4.3.3.7 Use of Data Link issues

The use of data link to support ground clearance and taxi route uplink in the cockpit may lead to additional human factors issues:

- Reduced situation awareness due to a loss of 'party line' audio communications.
- Non-zero error probability due to reading clearances from display or printout. The level of safety shall be reduced as the result of the change from voice-based communications systems to data-based communications system. Speech applications might be used to present messages, provided that they exceed actual comprehensibility level achieved with radio.
- Data presentation should aim at minimising any increase in flight crew head-down time; any increase of head-down time shall neither compromise safety nor reduce flight crew situation awareness.
- Voice and data link communication procedures shall be consistent in the dual media controller-pilot operational communications system.
- Excessive workload from manually entering data for transmission from aircraft (acknowledgement, negative response due to problems).
- Means to alert the flight crew that a message has arrived.
- Additional perceptual burden placed on visual system (channel overload). Attention shall be paid to minimise flight crew visual attention to display any information that will interfere with attention to high priority tasks.

4.3.3.8 Auditory and Visual Perception issues

Auditory and visual perception occupy different regions of the cognitive brainwork. A number of accidents occur when the pilot is under heavy visual workload. Despite the visual system, the auditory system does not require direct attention to a certain direction to perceive stimuli. There is no need to scan a display or to search for a certain value. Auditory stimuli have the advantage of attracting attention immediately. The danger of trusting in auditory signals lies in false interpretation or wrong understanding of what was emitted. Also, one has to consider that most communication within the cockpit is auditory. Thus, two auditory information sources at the same time could lead to confusion and distracting. Another problem is to match the auditory information, which is of more value for the operator. That is the reason why designers prefer to apply auditory information only in emergency situations. An operator under stress can become over-aroused when presented with extra auditive signals, causing performance to deteriorate (Wickens, 1997). More useful can be the application of spatialized auditory head-up displays. By using the 3D possibilities, the sound can come from any given position. This allows the pilot to stay focused in his view outside the window. The spatialized auditory HUD displays could also help visual search. The application of auditory displays can be used to enhance aerospace safety and situational awareness.

4.3.3.9 Roles and responsibility issues

From a human factors perspective, A-SMGCS developments could be expected to influence on autonomy and role changes between flight crews and controllers. The unambiguous delineation of responsibility between flight crew and controllers is a fundamental principle of safe air travel under any set of procedures and technology. In the future the roles and responsibilities for maintaining separation on the ground may be dynamic and change between flight crews and controllers (ASAS-like function); however more responsibility for monitoring and maintaining their own separation through cockpit display may result in crew workload increase and head-down issues.

4.3.3.10 Training and Procedures issues

Workload and cognitive demands may also arise due to new procedures, tightly coupled supporting systems, increasingly complex software configurations, active user collaboration, and dynamic air traffic situations.

Flight crews in the A-SMGCS environment will require different skills than those needed in the current environment. With the introduction of planning, routing and guidance services, automation will be heavily relied upon. There is a need to address current and new training requirements for the flight deck concepts.

New procedures may thus be required for flight crews to operate and manage the flight deck future environment. Similar to training, a critical issue will be to determine the procedures the flight crew must perform to operate and manage a system in both normal and abnormal modes of operation. These should be as intuitively obvious as possible so the flight crew can perform its duties in an effective and efficient manner with a minimum chance of error.

4.3.4 Vehicle Drivers' Considerations on Human Factors

This guidance function provided to the vehicle driver consists in an airport map showing taxiways, runways, obstacles, the vehicle's position, and the vehicle's destination. The corresponding human factors issues encompass:

- Drivers' situational awareness
- Drivers' head-down times.

4.3.4.1 Drivers' situational awareness

For the driver of a vehicle (baggage, follow me, airport patrol, fire & rescue, etc) situational awareness is given if the driver is aware of:

- The airport layout (including restricted and hazardous areas)
- The vehicle's current position on the airport,
- The vehicle's destination,
- The position of (permanent) obstacles on the airport,
- The position of other traffic on the airport, and
- The responsible controller for and the "authorisation status" of the vehicle.

The guidance function that is provided to the driver comprises an airport map showing taxiways, runways, obstacles, the vehicle's position and its destination. It can be assumed that those aspects of situational awareness will be substantially improved. This holds especially for low visibility conditions. Because the driver will be supported in finding his or her way on the airport, navigation mistakes and, consequently, unauthorised entries to restricted areas become less likely.

It should be noted, though, that there are aspects of the driver's situational awareness that will not be improved by the guidance function in A-SMGCS level 2. These relate to the position of other traffic on the airport as well as to the authorisation of the vehicle to enter restricted areas.

4.3.4.2 Drivers' head-down time

Head-down time for the driver results from the fact that the driver will monitor the guidance map while navigating around the airport. A problem with head-down time occurs if the driver allocates too much attention to the guidance map and misses relevant information that can be obtained by looking out of the window.

For the driver, the head-down problem qualitatively differs from the head-down problem described for the controller. This is due to a number of reasons:

First, it can be assumed that the driver would use the guidance map not only in low visibility but in all visibility conditions;

Second, the information provided in the moving map does not cover all relevant information required to navigate safely on the airport. Most importantly, the airport moving map will display the current position of the vehicle on the airport, but will not show other traffic on the airport. For this reason, the failure to monitor the outside view can result in collisions with other traffic on the airport.

Therefore, it is important to ensure that the driver will be trained on dividing his/her attention adequately between the outside view and the guidance map.

4.3.4.3 In-vehicle collision avoidance warning: false alarms and over-reliance

The importance of warning systems designed to alert the driver is increasing. Studies that have been conducted on car systems show that because the acceptability of imperfect aiding devices is increasing, particular caution should be paid to the use of such devices.

Attention shall be paid to reduce the potential rate of false alarms because they could distract the driver from real hazards by requiring her/his attention to normal situations. The degree to which the reliability of the warning system would affect the driver's usage of the system is a critical human factor issue. In case of missed alarms, over reliance on the warning system would be hazardous.

On the other hand, preliminary studies have shown that drivers are more cautious when using warning systems (drive more slowly) compared to driving without them. However studies shall be conducted in the airport context to analyse the driver reliance on warning systems and warning systems reliability, response time to alerts, cued versus non cued drivers' results.

4.3.4.4 In-vehicle routing and guidance service

Relevant studies have concentrated on driver distraction and inattention whose critical issues are mainly due to in-vehicle distractions (mobile phone, controls, displays, discussion with another people). As vehicle drivers spend the majority of their time looking the outside view (head up), an important issue relies in the potential head-down consequences of conventional electronic moving maps (routing & guidance) in vehicles. Thus in-vehicle head-up/multimodal displays should be envisaged.

4.3.5 Airline users

Aircraft manufacturers have made proposals where to locate displays in the cockpit: either dedicated or multifunction displays to best give the flight crew the required enhanced situational awareness; how alerts are indicated and supported by voice messages has to be evaluated; the timely involvement of pilot representatives is highly recommended in order to safeguard a sound acceptance in routine operations.

Flight and training departments of airlines will have to develop procedures, i.e. task sharing in had-up/down phases amongst flight crews, how to handle warnings and alerts.

From a human factors point of view there shall be no different set of flight crew procedures from one airport to the other.

Some danger might arise like with TCAS when airborne: the still existing possibility of non-relevant TCAS resolution advisories in dense traffic areas shall not be repeated on the ground.

On the other hand, forced disregarding of warnings and alerts would considerably reduce confidence in such service.

5 Initials EMMA Proposals for A-SMGCS Implementation Packages

The basic idea of this chapter is to identify "implementation packages" to support the stepwise implementation of an A-SMGCS. The EMMA "implementation packages" go beyond the EUROCONTROL, EUROCAE, and ICAO "implementation levels" through the definition of higher levels for A-SMGCS automated <u>services</u> including <u>equipment</u> and <u>procedures</u> considerations.

The new term "packages" was chosen to delimit from the "implementation levels" definition that were identified as insufficient to assist the stakeholders to implement a complete A-SMGCS in a stepwise approach. EUROCONTROL's and EUROCAE's 4 implementation levels definition focuses on the main four A-SMGCS functions, which is relevant for *surveillance* and *control* because the functions base on each other in a successive way. Further on, these two services are mainly used to assist the users, thus procedures do not have to be changed fundamentally.

However, the implementation of routing (planning) and guidance automated services increases the complexity of the A-SMGCS system as several options exist in terms of automated support to the users and their operational use lacks currently maturity.

Careful consideration shall be made on changing operational procedures, shifting responsibilities from human to equipment (visual reference vs. electronic display), introducing onboard automated services, and equipments, as well as on the interrelations between the A-SMGCS functions. The EUROCONTROL and EUROCAE level 3 and level 4 descriptions do not provide sufficient information. ICAO goes a step further and considers the responsibility shift between controllers, pilots, and equipment for higher levels but does not give sufficient information by which procedures the system is used nor it describes what the technical enablers are and what level of service the users can expect.

5.1 Generic EMMA Service Steps

EMMA aimed to extend EUROCONTROL's level 1&2 definition by a detailed description of higher A-SMGCS services that include guidance, routing, planning, and onboard services, as well an extension of surveillance and control services.

Therefore, the first step was to contour higher A-SMGCS services (see section 2). A second step was to allocate appropriate technical enablers that are needed to fulfil the service requirements.

A third step was to group services and technical enablers in order to establish successive implementation steps that base on:

- Development status of the service (already validated by operational life trials or under investigation through simulation or only at the stage of a concept)
- Development status of the technical enabler (standardised, on the market or to be developed yet)
- Degree of interrelations to other functions (complexity)
- Quality of the enabling equipment (needed reliability)
- Impact on current operational procedures and size of the changes
- Cost/benefit considerations

The individual steps for each A-SMGCS service, which were agreed among EMMA partners[33], can be found in section 3.

[33] Beside industry and R&D representatives there were representatives from ANSPs (ANS_CR, ENAV, DSNA, AENA, DSF) and Airlines (CSA and DLH).

The objective of this section is to map such individual implementations steps to the proposed implementation packages. Such individual service steps shall not be considered in isolation but their interdependencies as well as the required technical enablers need to be considered. For instance, there is no value to implement a “route deviation conflict alerting” function when the taxi route is not known to the alerting function, that is, a routing function has to be implemented first.

Figure 5-1 attempts to depict the arrangement of individual steps for each A-SMGCS service in a logical order. The services are arranged to the main users: ATCOs, Flight Crew, and Vehicles Drivers. Concerning ATCOs the services comply with the main A-SMGCS functions: surveillance, guidance, routing, and control. Flight Crews and Vehicles Drivers receive an onboard service by different characteristics (see §2 for more details).

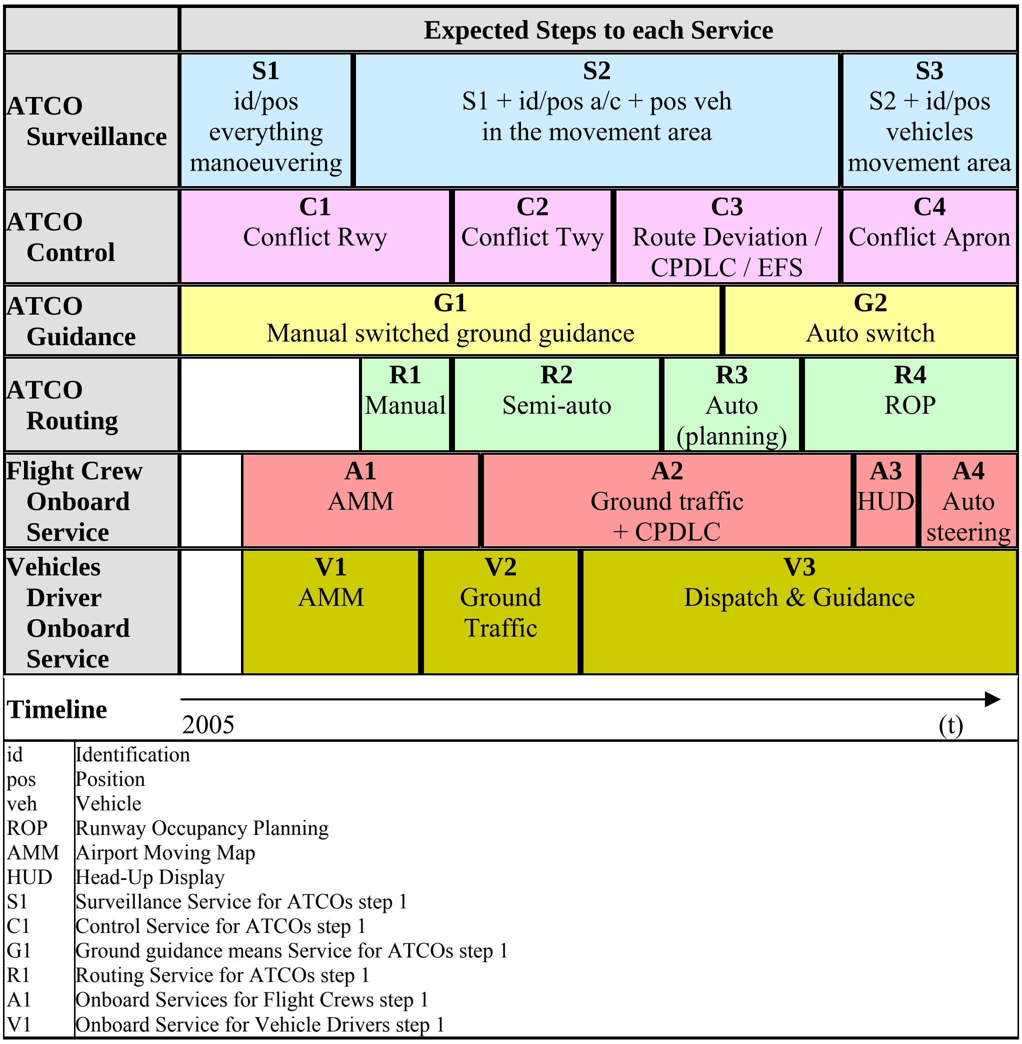


Figure 5-1: Logical order of EMMA Service Steps

Switchable ground guidance means will not further supported with EMMA implementation packages. To install ground guidance means on an airport, which would meet the requirements for such a service, has been estimated as rather expensive without significant relation to its benefit. However, when switchable ground guidance means are already available at an airport (e.g. Heathrow); they should be considered as an additional A-SMGCS service (particularly useful with unequipped aircraft in low visibility).

5.2 Proposed Initial Implementation Packages

Clustering of these different service steps to *packages of implementation* should reflect the operational needs for the considered airport.

Such operational needs vary from one airport to another depending on local circumstances such as the complexity of the airport layout, the number of days of low visibility, the amount of traffic, the information flow, the traffic mix, amount of personnel, etc.

The airport-specific characteristics and the current operational procedures are important factors in order to meet the safety objectives while optimising the efficiency of surface movements and will imply significant differences in A-SMGCS implementations.

These safety and efficiency operational objectives considered on top of A-SMGCS have been set by ICAO A-SMGCS Manual:

A system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety. [1]

5.2.1 Proposed Criteria for A-SMGCS Implementation

It is observed that A-SMGCS is currently deployed for complex airports (more than one runway) and with significant traffic of medium or heavy aircraft. In addition, visibility conditions applicable for A-SMGCS operations represent a further primary criterion. The following table depicts a first decomposition of A-SMGCS in implementation packages according to the proposed criteria:

Layout	**Traffic density**	**Visibility**			
		Vis 1	Vis 2	Vis 3	Vis 4
COMPLEX	Medium	Implementation Package (IP) 1	IP2	IP3	IP4
	Heavy	IP5	…	…	…

Table 5-1: Implementation Package Matrix

For each cell of the matrix Implementation Packages have to be designed to meet the operational needs. The balance pivot, when clustering services to "implementation packages" to provide *safe* and *efficient* surface movements under specific side conditions (visibility, layout, traffic), are the procedures to be used operationally. For instance, in visibility condition 3 the ATCOs are assisted by A-SMGCS surveillance and alerting services but they are not allowed to use such services as a primary source of information through relevant operational procedures, potential safety benefits will be gained but no change to throughput restrictions (procedural control) will be enabled.

The same applies to planning or onboard guidance. Introduction of these services apart from the right procedures that can influence the behaviour of the traffic would not lead to throughput benefits. The equipment, on the other hand side, is more seen as a catalyst or as a prerequisite to evoke a potential service. But procedures are always the core to enable a service to meet the operational needs.

Initial procedures developed in EMMA are outlined in the D135 EMMA Operational Requirement Document [21]. These initial procedures for higher A-SMGCS levels are still lacking of maturity but are used as a starting point to form EMMA implementation packages. In the successor project EMMA2 these procedures will be tested in simulation exercises and updated by the gained results.

5.2.2 Implementation Package 1

Concerning Table 5-1 this IP is aimed a complex airport (> one RWY) with medium traffic density (< 35 movements/h) operating under VIS1. That is, the ATCO can control the traffic by visual reference at all times and everywhere and the traffic is not as heavy as the ATCOs or Pilots reach their mental capacity limits. A-SMGCS shall help here to provide surveillance (position and identification = S1) of aircraft and vehicles on the airport manoeuvring area to enhance ATCO's situation awareness (SA), to complete ATCOs situation assessment (e.g. who is who in a taxi queue far away from the control Tower or to allow them to go without pilot position reports). Further on, a runway safety net (C1) warns ATCOs about potential runway incursions. All this would contribute to safety and efficiency.

Optional: Since an Airport Moving Map (AMM) with its basic service (showing the position on the ground) is independent on ground equipage, Airlines and Airports could equip their aircraft and vehicle fleets with an AMM (A1 + V1) to increase the pilot's and driver's situation awareness what would increase safety again. Automatic routing or ROP (R3/R4[34]) could be initiated when the surface movements are identified as too inefficient compared to runway or gate capacity. When the route is known to the system it can be transferred onboard via data link provided that aircraft are equipped with CPDLC service (A2) and provided that an input device for the ATCO and proper procedures are available.

5.2.3 Implementation Package 2[35]

The side conditions with IP2 are the same as with IP1 except that VIS2 is predominating now, i.e. the ATCO cannot see the traffic outside. Therefore, the ATCO should be provided with a surveillance that covers the complete movement area with position and identification information of all aircraft (S2). Since pilots and vehicle drivers can still see and avoid each other, conflict alerting service is concentrated on the runways (C1) where providing separation is the most difficult and safety critical part.

Optional: A Ground Traffic display showing the surrounding traffic by receiving TIS-B information (A2 + V2) would be an option to increase safety. As surveillance covers the whole airport also conflict alerting extended to the taxiway could be implemented (C2). However, detection of conflicts on taxiways by automation is a very complex task because much information has to be known to the control function, e.g. the cleared taxi route. That is why, it is assumed that *see and be seen* principle is sufficient under VIS2. When the route is known to A-SMGCS CPDLC (A2) can be implemented as well to increase safety and efficiency.

5.2.4 Implementation Package 3

Visibility decreases further so that pilots are not able to avoid each other anymore (VIS3). Conditional taxi clearances (e.g. "follow the CSA 737 coming on…") that base on the pilot's ability to see and avoid the other traffic cannot be applied anymore. Currently ATCOs take into account these new limitations and give taxi instruction following procedural control operations (one aircraft only within a specified area). Those procedures for low visibility operations (LVO) (PANS ATM, doc4444, §7.10) maintain safety (as the topmost objective) but on the expense of throughput.

A solution to maintain safety and throughput would be that aircraft are still able to see and avoid each other by providing them a step 2 onboard service (A2). A2 enables them to see the surrounding traffic by receiving surveillance information from ground stations (Ground traffic display enabled by ADS-B

[34] Manual (R1) and semi-automatic (R2) routing are identified as implementation steps and are certainly needed to evolve automatic routing (R3) at an airport. However, working with R1 and R2 are rated as too inefficient as they would support the ATCOs – therefore these first implementation steps are not considered with A-SMGCS implementation packages.
[35] In general, IP2 complies with EUROCONTROL implementation levels 1&2.

in and TIS-B). The main issue with this solution is the transition phase: It would be needed that all movements are equipped with this service because non-equipped movements cannot avoid other ones and they cannot be controlled in a mixed mode environment. Even when A2 would be the best solution it cannot be assumed that all aircraft are equipped from one day to the next. That is why this solution cannot be preferred for the near future.

A first interims solution would be to assist the ATCO[36] to provide the control service for all movements on the movement area. The runway safety net (C1) would be extended to cover potential hazardous situations on the taxiways and aprons (C2 + C4) and a route deviation alerting service is added (C3).

To make the route known to the system, automatic routing should be available (R3). Surveillance would have been extended to step 3 (S3), which would enable the use of electronic display by Apron Managers to provide traffic information to aircraft and vehicles for the apron area as well.

However the control of the whole apron area would be hard to achieve on the basis of using only surveillance display, the Apron managers would only be responsible for designated areas of the apron area (taxi lanes, active stands, passive stands). Only authorised movements (vehicles must be equipped and must ask for permission to enter) would be permitted to use such areas. Other movements would be restricted to parts of those areas (ICAO doc 9830, §3.5.16.3, [1]).

A second and perhaps more likely interims solution would be to equip vehicles, which have to move on these designated areas, with a ground traffic display (V2). This would enable them to receive warnings when risk of collision with moving aircraft exists.

Which solution will be applied finally is much dependent on the airport layout, local procedures, and decisions met by the local stakeholders.

Optional: Since S2 is available (includes TIS-B) a ground traffic display (A2) could be used by the airlines to increase situation awareness and efficiency of taxi movements. Routing can be extended to a ROP (R4) when cost/benefit data support this implementation.

5.2.5 Implementation Package 4

Visibility is now insufficient to taxi by visual reference. Onboard service has to be extended to step 3 (A3) that includes a head-up display (HUD) that enhances the pilot's local situation awareness by a HUD scene linked enhanced outside view. Step 2 surveillance (S2) and step 2 control (C2) assist the ATCOs and provide them the required situation awareness. Vehicles are equipped with ground traffic displays (V2) whereby they can move without additional traffic information from ATCO.

Optional:

Service to flight crews can be extended by an auto steering function (A4), which keeps the aircraft on the yellow taxi line automatically. Additionally, alerting can be extended to the apron area (C4) and automatic routing (R3) and ROP (R4) can be implemented if shortages with safety or efficiency are found.

5.2.6 Implementation Package 5 through 8

IP5 through IP8 are designed for the operational needs of complex airports with heavy traffic density, greater than 35 movements per hour. Since the traffic density is very high and thus the human operators often reach their capacity limits, surveillance should always be step 2 (S2) and control should always be step 3 (C3). S2 and C3 provide the ATCO with a complete surveillance and safety net of the overall movement area. This increases mainly safety. To increase or maintain throughput automatic routing including runway occupancy planning (ROP) (R4) should be implemented to support the users by optimised and negotiated times and taxi routes (on a CDM basis).

[36] At some airports there is a separate Apron or Ramp Control that are not ANSP. However, within this context the ATCO term is also used for non-ANSP control units.

With VIS3 (IP7) it is insufficient for pilots to avoid collisions with other traffic by visual reference. As mentioned above with IP3 the ATCO should be provided with an additional safety net that detects conflicts not only on the runways and on the taxiways but also on the apron areas (C4). Vehicles moving on the designated apron areas (where they can conflict with aircraft) should be equipped with a ground traffic display (V2) to see the surrounding traffic and to avoid it.

With VIS4 (IP8) it is insufficient for pilots to taxi by visual guidance only. As with IP4, the onboard service has to be extended to step 3 (A3) that includes a head-up display (HUD) that enhances the pilot's local situation awareness by a HUD scene linked enhanced outside view.

Optional:

Optional but very beneficial with all IPs with heavy traffic would be step 2 service to flight crew and vehicle drivers (A2 and V2). With this service pilots and vehicle drivers are always able to see where they are, where they have to go, and where the surrounding traffic is. Particularly with dense traffic, this would contribute to safety, but also to faster taxiing what is an efficiency aspect. Vehicles can be equipped further on with vehicles service step 3 (V3) what would allow them to receive a taxi route, or the exact location of an accident, or other information via data link. This would particularly beneficial with VIS3 and VIS4 when they cannot see the destination by looking outside their windows.

Table 5-2gives an overlook to all 8 implementation packages:

Layout	Traffic density	Visibility			
		Vis 1	Vis 2	Vis 3	Vis 4
COMPLEX	Recommended Medium optional	IP1 S1 + C1	IP2 S2 + C1	IP3 S2+C3/4+ V2+R3	IP4 S2 + C2 + A3 + V2
		A1 + V1 R3/R4+A2+ V1	A2 + V2 C2+R3/R4 +A2 +V1	R4 + A2	C4 + A4 + R3/R4
	Recommended Heavy optional	IP5 S2 + C3 + R4	IP6 S2 + C3 + R4	IP7 S2 + C4 + V2 + R4	IP8 S2+C3+A3+V2+R4
		A2 + V2	A2 + V2	A2 + V3	A4 + V3

Table 5-2: Implementation Packages

6 Operational Environment

This section of the OSED is a vehicle for the general description of the operational environment for the A-SMGCS services described in the section 2. More specific environmental descriptions will be provided in D1.6.1 Test Sites Operations document for Praha-Ruzyně, Toulouse Blagnac, and Milan Malpensa.

The term 'operational environment' is defined here by those characteristics that form the descriptive basis of operations relevant for assessing the safety of flight operations.

The environment definition is fundamental to the process of developing safety, performance, and interoperability objectives and could be broken down as follow:

- Airport Areas, Airport Complexity and Impact of Weather and Topography
- Air Traffic Services at Airports
- ATC Operations at Airports
- Traffic characteristics

6.1 Airport Areas, Airport Complexity and influence of Weather and Topography

EMMA services address the following operations by aircraft or vehicles operating on the airport surface:

- Departing aircraft: all movements from parking position until take-off through apron, taxiway and runway
- Arriving aircraft: all movements from the landing phase until arrival at the parking position, through runway, taxiway, and apron.
- Local aircraft movement on the ground: Movements of non-departing/arriving aircraft.
- Airport vehicles: operations on the whole airport movement area, including aprons and the manoeuvring area.

As the project is related to ground (all pre-flight, in-flight and post-flight operations only), there is no need to describe any airspace characteristic due to its low significance.

6.1.1 Airport areas

The airside part of an airport consists of

- **Manoeuvring** area: That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons (ICAO).

  The manoeuvring area includes:

  - Runway(s) area (RWY), including interfaces between runways and taxiways;
  - Taxiway(s) (TWY)
  - Holding bays and bypasses as special TWY application,

- **Apron(s):** A defined area on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance.

  The Apron includes:

  - Apron taxiway(s) (to be discussed within EMMA II context)

- Stand taxi line(s)
- Stands/gates
- Servicing areas
- Service roads
- De-icing/anti-icing spots,

- **Movement area:** That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and apron(s).
- **Special use pavements**
  - Service roads outside the apron
  - Compass compensation and VOR/DME check points
  - Pavements for ground CNS installations and
  - Visual ground signalling area.

Additionally to that, specific ICAO CAT II/III LLZ sensitive area(s) can be defined.

The following areas of the airport are defined along with their use:

- Runways including holding positions: used for take-off and landing of aircraft;
- Taxiways: used for aircraft movements between the apron and the runway in use and vice versa;
- Apron: area used to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking and maintenance.

All of these areas may also be used by airport vehicles for maintenance, inspection, and service. All movements on the manoeuvring area (defined as runways and taxiways but excluding aprons) are controlled by the TWR. The movement area includes the manoeuvring area and aprons.

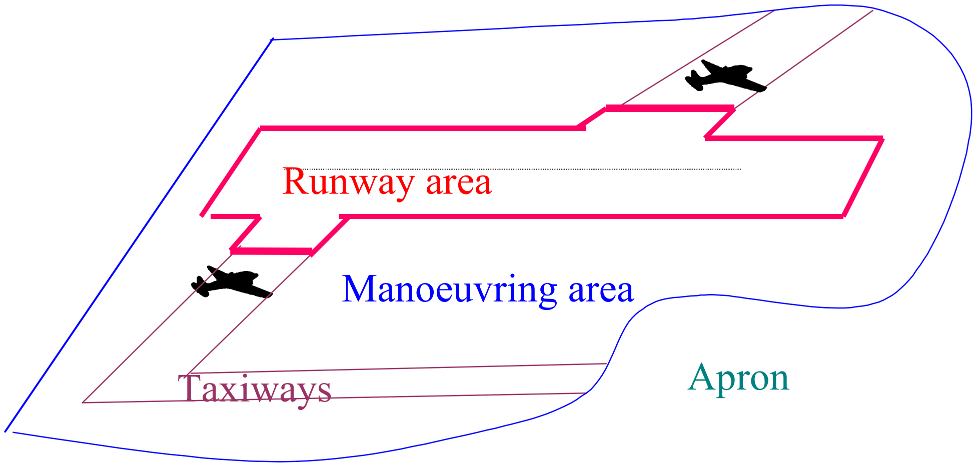


Figure 6-1 - Airport areas

6.1.2 Airport complexity and configurations

6.1.2.1 Complexity

Complexity is a generic term for description of level of difficulty of handling the air traffic. The level itself is than in fact an effect of synergy of several factors acting at the same time. Most dominant elements participating to the creation of complexity are traffic demand and characteristics of areas of responsibility. In the context of aerodrome control, the key elements are:

- Airspace characteristics and environmental aspects
  - CTR airspace classification
  - Departure routes structure
  - Approach procedures
  - Noise, pollution and vibration restrictions
- Aerodrome characteristics
  - RWY, TWY, apron and/or stands configuration, geometry and dimensions
  - Interface RWY-TWY and/or TWY-apron
- Traffic demand
  - Traffic amount
  - Traffic distribution in time
  - Arrival/departure ratio
  - Aircraft characteristics
  - Flight rules
- Other factors as may be relevant.

This document is described for airports characterised by a complex layout that require a high degree of vigilance by the air traffic controllers, flight crews, and vehicle drivers. Especially in adverse weather conditions, the complexity of these airports may create highly stressful situations for the aerodrome controllers and lead to misinterpretations and incorrect decisions by flight crew and drivers. The following items contribute to the complexity of the environment:

- Crossing runways or dependent parallel runways require a higher attentiveness when they are in operation at the same time;
- A runway might also be used as taxiway at the same time. This situation occurs when landing or departing aircraft have to do backtracks on the runway if existing taxiways interface runways in ineffective distance.
- An active runway might have to be crossed by aircraft taxiing to or from the parking positions or by vehicles operating on the manoeuvring area;
- The presence of multiple aprons, i.e. for passengers, freight, business, general aviation, etc., might create complex taxi procedures, especially when taxiways, runways or another apron have to be crossed. Furthermore, the airports under consideration have a high traffic mix of civilian, military, and training aircraft, VFR and IFR traffic, aircraft and helicopter traffic and passenger and freight flights. Mixed traffic requires high level of attentiveness when a large apron is divided in different parking zones or when several aprons exist for the different traffic categories.
- A taxiway system with a great number of intersections. Especially in bad weather conditions, the risk increases for incorrect decisions by controllers, flight crew or drivers;
- A taxiway that has to be shared by landing and departing aircraft or by aircraft and vehicles at the same time. These situations might occur when the apron has an unfavourable location in relation to the runway.
- Crossing flows of departing and arriving aircraft to and from different aprons or parking areas. This situation increases the risks of conflicts on the airport. Here again, there is a strong correlation with the weather conditions. Low visibility conditions add to the magnitude of the problem as they limit the use of visual methods.

6.1.2.2 Configuration

The configuration of all elements of the movement area is a subset of the complexity of the airport influencing it in a very intensive way. Except the traffic itself, the configuration of the manoeuvring area and aprons creates the most dominant part of difficulty level in provision of ATS having direct impact to safety, capacity, economy, effectiveness, and environmental issues.

There are many views on description of configuration of the aerodrome layout. As defined in ICAO A-SMGCS manual and related Eurocontrol documents, three basic models can be identified:

- Basic

  This configuration addresses single RWY systems with one TWY connected to one apron. Such an airport does not offer perspective ATM capacity and can create potential additional ATCO workload increase in sharing the TWY for inbound and outbound traffic as well as for ground vehicles. The necessity for backtracks brings enormous impact on RWY occupancy problems in terms of "forgetting" about such taxiing aircraft in context of lined-up aircraft ready for departure or aircraft in final approach and landing phase.

- Simple

  This configuration is an enhanced basic model by additional taxiways and possibly aprons so therefore such aerodrome offers greater variety in traffic handling capability. Separate taxi route circuits can be defined to separate aircraft taxiing for departure, aircraft after landing and even ground vehicles in both reciprocal operational modes. RWY capacity utilisation is easier in accommodating higher traffic demand.

- Complex

  As of complex aerodrome model is concerned, this is a solution for major destinations enabling utilisation of big traffic demand. It is composed of a multi-runway system equipped with a variety of taxiways and aprons. Such a configuration enables flexible use of each individual component in a different way reflecting constraints created by weather, capacity requirements and environmental and security aspects. On the other hand, such a complex system generates a lot of potential hazards during ATS provision as described in the chapter about complexity. Also interfaces between APP (ACC if practicable) – TWR and TWR – ground control or apron control is difficult to manage in case of reversing traffic flows. Due to the presence of enormous number of intersection nods (RWY-RWY, TWY-RWY, TWY-TWY) additionally accompanied by one way taxiway scheme there is a strong need for precise implementation of instinctive (even non-standard) ground guidance signs to minimize potential misinterpretation of cleared movement direction at those hot-spots while taxiing, both aircraft and ground vehicles.

6.1.3 Influence of Weather

The weather is a very important factor influencing the airport operations. The most disturbing atmospheric conditions are:

- Rain: it reduces the visibility and decrease the runway friction (related to brakes use) and may create clutter on SMR displays and generate false alarms on safety nets.
- Strong cross winds: it provokes changes in the runway configuration (reduce capacity in the transition phase) and difficult conditions at the last steps of the approach phase
- Snow and hail: it reduces visibility, covers visual and lighting aids, decrease friction, decrease the taxiways, runways, stands and de-icing areas availability and usually it is associated to icing conditions. After a heavy snowfall, a snow sweeping has to be carried out.
- Fog: it reduces the visibility
- Low temperatures – icing conditions: de-icing aircraft prior to take-off create additional

constraints for surface movements (e.g. maximum time between de-icing and take-off).

All these conditions will reduce the throughput at the airports.

6.1.4 Influence of Topography

Possible influence of topography in vicinity of airport:

- Undulated RWY surface directly affects possible application of some operational procedures (e.g. multiply line-up),
- Undulated TWY surface may create problems “to see and avoid” opposite traffic (e.g. aircraft versus ground vehicle taxiing at the same TWY)
- Vertical profile of surrounding terrain directly affect minimum descent altitude, glide slope angle and direction of instrument procedures,
- Living areas in a short vicinity of an airport are generally reason for creation of specific noise abatement operational procedures,
- Forests, aquatic areas and industry centres can have contrary effect on meteorological conditions on the airport and its vicinity in creation of good conditions for condensation of air vapour (low visibility conditions due to haze, mist and fog, creation of significant clouds and related local meteorological phenomena – wind shear, turbulence)

· Presence of buildings at the airport and its vicinity cause reflection and refraction of electronic signals used for surveillance as well as even blind areas

6.2 Air Traffic Services at Airports

6.2.1 General Objectives

According to ICAO PANS-ATM (Doc 4444) the objectives of the air traffic services shall be to:

1) Prevent collisions between aircraft;
2) Prevent collisions between aircraft on the manoeuvring area and obstructions on that area;
3) Expedite and maintain an orderly flow of air traffic;
4) Provide advice and information useful for the safe and efficient conduct of flights;
5) Notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required.

6.2.2 Aerodrome Control

Aerodrome control towers shall issue information and clearances to aircraft under their control to achieve a safe, orderly and expeditious flow of air traffic on and in the vicinity of an aerodrome with the object of preventing collision(s) between:

a) Aircraft flying within the designated area of responsibility of the control tower, including the aerodrome traffic circuits;
b) Aircraft operating on the manoeuvring area;
c) Aircraft landing and taking off;
d) Aircraft and vehicles operating on the manoeuvring area;
e) Aircraft on the manoeuvring area and obstructions on that area.

The functions of an aerodrome control tower may be performed by different control or working position, such as:

- Aerodrome controller, normally responsible for operations on the runway and aircraft flying within the area of responsibility of the aerodrome control tower
- Ground controller, normally responsible for traffic on the manoeuvring area with the exception of runways
- Clearance delivery position, normally responsible for delivery of start-up and ATC clearances to departing IFR flights.

Depending on the airport complexity and the traffic density, these positions can be split down. For example, where parallel or near-parallel runways are used for simultaneous operations, individual aerodrome controllers should be responsible for operations on each of the runways.

The complete description of Aerodrome Control is included in ICAO PANS-ATM Doc 4444 Chapter 7.

6.2.2.1 Control on the Manoeuvring Area

As a general rule, all traffic on the manoeuvring area is controlled by the control tower (TWR). At some airports, the aerodrome control may be shared between ground controllers (for taxiways) and aerodrome controllers (for runways).

Voice communication between TWR and aircraft is required to allow an aircraft to enter the manoeuvring area. However, depending on the airport equipment and the size of the airport, there may be additional requirements. For instance, on airports equipped with advanced surveillance system (MLAT, ADS-B…), it may be required to have a turned-on transponder onboard before entering the manoeuvring area.

No vehicles are allowed on the manoeuvring area without prior permission by voice communication or approved procedure not requiring voice communication to operate on the manoeuvring area. Access to and operation on the manoeuvring area for all vehicles, e.g. friction testing, snow clearing, fire and rescue (other than in emergency) and maintenance vehicles, are therefore based on clearances from the TWR provided by voice communication means.

Authorised vehicle traffic is normally allowed to operate on airport (transport) roads without permission from the TWR. However, under LVO, all traffic on specified airport roads is prohibited unless a clearance has been obtained from the TWR, while special rules may apply for traffic on other airport roads.

6.2.2.2 Guidance on the Manoeuvring Area

In the most elementary systems, guidance of movements on the aerodrome surface is manually performed by aerodrome controllers by giving instructions or manually operating stop bars and taxiway lights.

Ground controllers can instruct the flight crew through R/T messages either to take their own route, to follow a sequence of taxi lanes and taxiways or to follow a predefined route to the runway holding point for take off or from the runway exit to the stand after landing. Pilots and vehicle drivers rely on visual aids (lighting, signage, and markings) to guide them along their assigned routes and to identify intersections and holding points issued by the controller.

6.2.3 Apron Management Service

Apron Management Service is defined by ICAO as a service providing apron instructions to regulate the activities and movement of traffic and any other vehicle operating on the apron (typically handling services).

Control provided on the Apron is not control in real sense of the word. It is rather management and does not require licensed ATCOs. Based on local institutional arrangements, apron function can be covered solely by local ANSP, airport operator or by ANSP and airport operator joint operations. The task of providing specified services on the apron, e.g. apron management service, may be assigned to an aerodrome control tower or to a separate unit-. Apron control is a special ground movement control application. The service is restricted to issuance of taxi instructions and information to flight crews about known traffic. Whereas a dedicated apron control unit, often referred to as Apron Tower (ATWR), handles traffic on aprons on some airports, this unit only manages the gate allocations in other airports. In special cases, due to the layout of the airport, the control of taxiing aircraft on parts of the manoeuvring area might be delegated to the ATWR when weather and traffic load permit.

6.2.4 Approach Control

The approach controller is responsible to handover the aircraft to the aerodrome controller when the aircraft is close to the RWY (the distance depends on the procedure) and stabilised for landing.

This role is out of the scope of A-SMGCS but it is included here for clarification

6.3 ATC Operations at Airports

ATC operations at airports encompass the provision of control and guidance for all aircraft and vehicles on the manoeuvring area and may sometimes also include the provision of the apron management service for aircraft.

The section puts an emphasis of low-visibility operations, where significant safety-efficiency-capacity benefits should be obtained from A-SMGCS implementation.

6.3.1 General Description

This section presents an overview of the ATC operations for arriving or departing flights as well as for other traffic such as airport vehicles.

6.3.1.1 Inbound Flight

For aircraft on approach to an aerodrome (entering the system focus), flight plan data are generated 20 minutes before entering the control sector. Such data will be distributed by the Radar Data Processing Systems (RDPS) and the Flight Plan Data Processing System (FDPS) either in a printed form (flight strips) to each concerned control position or presented electronically to the controller on a flight data display.

Where an update (e.g. revised estimates for time over the initial approach fix) of the flight data to all concerned control positions in relation to each particular flight progress is achieved automatically within a local area/approach control facility, a similar transfer of such data to adjacent ATC units (e.g. TWR) exists for large airports but not necessarily for smaller ones. Please refer to the final release of D1.2.1 for details on new EMMA proposals to cope with this issue.

When an aircraft enters the final approach segment, the aircraft control is transferred to the aerodrome controller at a distance established in the Letter of Agreement. Having received the pilot's initial call, the aerodrome controller will assume control, and issue a landing clearance dependent on the traffic situation. Prior to the landing the Flight Crew has selected one runway exit (approach briefing), an advise for runway exit may also be provided by the aerodrome controller.

After landing the aircraft exits the RWY, the ground control position will provide the pilot with proper taxi instructions according to the actual traffic situation.

On the way to the Apron area the pilot may be provided with gate/stand information where such regulation between ATC and the airport authority have been agreed.

At aerodromes where an Apron management facility has been established, GND or even aerodrome controller, dependent on the procedures applied, will guide the aircraft from the Manoeuvring area to the Apron area to a standard designated hand-over-position located on the boundary between the concerned areas of responsibility. After hand-over to the Apron controller, the aircraft will be guided to its final gate/stand position having regard to any other conflicting traffic of aircraft and/or vehicles on the movement area of the Apron.

Additionally, in some cases, standard taxi routes may be implemented according to the 'one way principle'. Such routes are determined by ATC together with the airport authority, and allocated according to the Active Runway in order to separate aircraft taxiing to the apron from those moving to the runway.

Such regulation as suggested by ICAO (Doc. 9476 Manual of SMGCS), will provide for conflict-free traffic movements in both directions wherever the infrastructure of an aerodrome will permit. It appears to be worthwhile mentioning that, where such procedures are practised, the applied regulations have proven to be of considerable efficiency.

6.3.1.2 Outbound Flight

Before an aircraft is ready for start-up, the pilot will contact a clearance delivery position responsible to issue the departure clearance (contains SID, route to destination, initial flight level and local meteo information). The departure clearance is issue using the Flight Data Processing System (FDPS).

As soon as an aircraft at a gate/stand position is ready for operation (CFMU slot will be considered), pilots will contact GND (or sometimes clearance delivery) and request start-up. and push-back clearances.

Note: Push back is performed during the engine start up as most of the push back tugs are unable to perform pushback when all engines are at idle power (especially when 3 or 4 engines jet aircraft are involved)

When no Apron management facility is established, the pushback clearance is issued by the ground controller.

When ready to taxi the pilot will request taxi instruction from GND, which includes the routing from the parking position normally to the holding position at the RWY. The ground controller assigns the shortest taxi route to the aircraft, potential conflicts with other traffic is not addressed prior to taxi movements.. At the runway holding hand-over will be made from GND to aerodrome controller.

The runway controller issues the line-up and take-off clearances that establish the required separation between consecutive departures (e.g. 2 min) or between arrivals and departures .

In other cases, where Apron management facility has been established, the pilot, having received the start-up clearance, will contact APN indicating that he is starting the engines. When ready for taxi (at taxi-in / taxi-out positions), taxi instructions will be requested.

Note: in the event of existing apron control facilities departure and start-up clearances are received separately.

On taxi-in / pushback gates/stands, permission for pushback will be requested. APN will issue permission for pushback in accordance with operational conditions at the parking position and consistent with designated and published pushback procedures.

Respective procedures have been defined considering the taxi-direction to the active runway along with standardised taxi routes (where applicable), as well as in accordance with measures to meet the adjacency problem regarding other types of aircraft in the neighbourhood, which may come in conflict.

After pushback, when the pilot has indicated to be ready for taxiing, APN will issue the taxi instruction to a designated hand-over position between the Apron area and the Manoeuvring area in the direction of the active runway. Under normal conditions, the hand-over will be accomplished while approaching the hand-over position, in order to support continuous and uninterrupted taxi movements.

Either GND and or aerodrome controller (as applicable) will subsequently assume control and guide the aircraft to its holding position at the runway.

6.3.1.3 Other Traffic

The movement of single objects, other than aircraft in operation are differently organised on the movement area of aerodromes.

Whereas in the manoeuvring area every intended movement of single objects or persons has to be reported to ATC and a special permission is to be obtained either by telephone or radio, there are movements on the Apron area, where vehicles may operate without any particular instruction and/or approval of the Apron management service. Such operations rely on the “see and be seen” principle as applied by the concerned drivers. Very often Apron service roads are implemented to cross taxi tracks or taxi lanes which are not protected by signage or any other means.

In many cases, ATC is responsible for taxiing aircraft in the Apron, while the airport's (passive) Apron management service is in charge of the provision of gate number to aircraft. Regarding the movement of vehicles on the apron, vehicles are following the standard driving code.

At a number of busy aerodromes, where the aforementioned conditions were no longer acceptable, active apron management services have been implemented in order to minimise collision hazards, and to ensure safe and efficient Apron management operations, including competent and flexible gate/stand manoeuvres.

Under all conditions mentioned above, the intended movement of every towed aircraft is subject to an announcement prior to the operation, either to the Apron management service and/or to ATC (depending on the towing operation). The unit in charge will then issue a permission including the designation of the new destination on the airport’s surface and, where part of the manoeuvring area is to be crossed or joined, then necessary co-ordination with ATC will be performed.

In most cases, tow-trucks are equipped with radio, and communication between APN/ Aerodrome control/ GND and the vehicle concerned is established

6.3.2 Low Visibility Operations

This section gives an overview of Low Visibility Operation. These operations are more detailed in the EMMA Operational Requirement Document Update D1.3.5u, which describes the Visibility Conditions defined by ICAO and also introduces the ATCO concerns on Visibility Transitions in the context of utilisation of A-SMGCS.

6.3.2.1 Visibility conditions

Mist and fog are in Europe the primary causes for visibility restrictions of operational significance; heavy precipitation may also cause low visibility, restricting aircraft operations and snow is one of the most common factors reducing visibility in cold climates.

ICAO (European Manual on A-SMGCS) has defined low visibility conditions, both for day and night, as follows:

- Visibility condition 1: *Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, and for personnel of control units to exercise control over all traffic on the basis of visual surveillance;*
- Visibility condition 2: *Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance;*
- Visibility condition 3: *Visibility sufficient for the pilot to taxi but insufficient for the pilot to avoid collision with other traffic on taxiways and at intersections by visual reference with other traffic, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. For taxiing this is normally taken as visibilities equivalent to a RVR less than 400 m but more than 75 m;*
- Visibility condition 4*: Visibility insufficient for the pilot to taxi by visual guidance only. This is normally taken as a RVR of 75 m or less.*

When it is planned to conduct operations at an aerodrome in low visibility conditions, identified in conditions 2, 3, and 4, there is a need to develop special procedures to ensure that these operations can be undertaken safely reducing the risk of inadvertent runway intrusion or collision on the ground among aircraft and/or vehicles and/or infrastructures.

It must be note that according to ICAO PANS-ATM these procedures apply whenever conditions are such that all or part of the manoeuvring area cannot be visually monitored from the control tower.

These operations are supported by special procedures named *Low Visibility Procedures.*

6.3.2.2 Low Visibility Operations (LVO)

Preamble:

"ATC management procedures, when manoeuvring areas are in such reduced visibility than the control tower can no more monitored the situation visually, are described as Low Visibility Operations in ICAO DOC 4444 § 7.10 (Only Additional requirements are requested for CATII/III operations). In Europe application of ECAC regulation and consequently JAR OPS-1 have led to set up Low Visibility Procedures (LVP) when airports are providing CAT II/III operations and LVTO. There are today a lot of interpretations that sometimes mixed those two different parts of the aerodrome regulation texts, these generating very different local procedures not always in line with both generic independent documents. The ICAO PT LVP is working to publish a document (ICAO EUR Doc 013 - still draft) that will encompass all the aspect of reduced visibility management at airports. As a consequence parts of the document hereafter are also subject to interpretation that will be taken up as soon as ICAO will deliver the final EUR Doc 013."

LVP are defined by ICAO as specific procedures applied at an aerodrome for the purpose of ensuring safe operations during Category II and III approaches and/or Low Visibility Take-Off.

The types of operations that will require LVP to be established are:

- Approaches and landing operations in CAT II and CAT III weather conditions
- Departure operations in conditions less than a value of 550 m RVR (plus a ceiling value)as stated in PANS-ATM 7.10.2, even if some States may use the value of 400 m RVR

The types of operations allowed are assessed by the Regulatory Authority of the Aerodrome and published in AIP.

A safety assessment must be carried out in accordance with the appropriate ICAO documents (Annex 11, Annex 14, PANS-ATM) in order to assess the magnitude of any increase in operating risk due to the lack of control by visual means.

The purpose is to eliminate the risk by the application of ATC control techniques (procedural control) and operational procedures (minimum separation and restriction of movements on the manoeuvring area), as well as the use of special visual aids (e.g. stop bars or taxiway adge lights). These measures constitute the LVP for the aerodrome.

These procedures simplify ground traffic patterns – whenever possible a single taxi route is available from the apron to the runway and vice-versa with intermediate intersections closed - and provide the pilot with clear unambiguous guidance on routing and holding points; maintain in the movement area only vehicles essential to the operation and driven by formally authorized and tested drivers.

6.3.2.3 Low Visibility Procedures specifications

Low Visibility Procedures are addressed mainly to ATCOs and to those responsible for the operations on the aerodrome, but also pilots play an important role.

They should specify at least:

1. The RVR value(s) at which the low visibility operations procedures shall be implemented;
2. The minimum ILS/MLS equipment requirements for category II/III operations;
3. Other facilities and aids required for category II/III operations, including aeronautical ground lights which shall be monitored for normal operation;
4. The criteria for and the circumstances under which downgrading of the ILS/MLS equipment from category II/III operations capability shall be made;
5. The requirements to report any relevant equipment failure and degradation, without delay, to the flight crew concerned, the approach control unit and any other appropriate organization;
6. Special procedures for the control on the manoeuvring area, including:
   - The runway holding position(s) to be used;
   - The minimum distance between an arriving and a departing aircraft to ensure protection of the ILS/MLS sensitive and critical areas;
   - Procedures to verify that aircraft and vehicles have vacated the runway;
   - Procedure applicable to the separation of aircraft and vehicles;
7. Applicable spacing between successive approaching aircraft;
8. Actions to be taken in the event low visibility operations need to be discontinued, *e.g.* due to equipment failure;
9. Any other relevant procedures or requirements.

6.3.2.4 Low Visibility guidelines

All airports supporting Cat-II and CAT-III precision approaches shall have LVP established. The limit for CAT-I operations I currently being harmonised at 550m of RVR and/or 200 ft of ceiling.

To smooth the transition from normal operations to LVP (as airports do not comply really with LVO) most of the airport implements safeguarding procedurs that start with higher values of VIS/RVR/CEILING and decrease progressively the runway(s) capacity.

Procedures required for low visibility operations vary with each aerodrome and their development must take into account local conditions, *e.g.* the point at which LVP should be implemented may initially be related to a specific RVR/cloud base measurement (generally 1000 m /200 ft) in a worsening weather situation and it will be dependent on the rate of weather deterioration and the amount of lead time necessary to implement the extra measures.

However the following guidelines may be outlined:

1. All drivers and personnel authorized to operate in the movement area must be adequately trained;
2. The point at which LVP come into operation must be clearly defined;
3. All non-essential vehicles and personnel must be withdrawn from the manoeuvring area;
4. Essential vehicles authorized in the manoeuvring area should be kept to the minimum and must be in RTF communication with ATC;
5. Where the possibilities of inadvertent entry onto the manoeuvring area exist and where physical closure is not practical, entry point should be manned;
6. All personnel not essential for performing the operation should be withdrawn from the movement area;
7. Appropriate emergency procedures must be developed.

6.3.2.5 Safeguarding measures

The meaning of “safeguarding issues” is the progressive implementation of parts of additional requirements e.g. using stand by electricity power unit or closing of all ILS electronic shelters at higher values of VIS/RVR/CEILING than the minimum required by the regulation. Each step could be linked to a reduced capacity figure. Mandatory spacing to protect CAT II/III and LVTO are implemented only at the same time LVP is published for pilots on the ATIS

There is a need for specific safeguarding measures to guarantee the protection and surveillance of the manoeuvring area against unauthorized incursion of vehicles/aircraft/persons on the runway/taxiways or in the critical and sensitive area around the antenna of the guidance equipment (ILS-MLS) in order to maintain the integrity of the guidance signal.

The number and size of the critical and sensitive areas will depend on the type of the guidance means in use.

Runway access taxiways that are not essential for entrance to or exit from a particular runway should be closed using taxi-holding position lights, traffic control lights, red stop-bars, or physical barriers/unserviceability markers.

Whenever possible there should be a limitation on the number of routes used for taxing to/from the runway, these should be identified, marked and published for the use of aircraft operators.

6.3.2.6 Surface movements

Among the LVP objectives there is also to provide the means to maintain the safety of movements on the ground.

The primary mean for collision avoidance in low visibility is the implementation of a procedural control scheme implemented as soon as part or all the aerodrome surface is no more visually in sight from the aerodrome controller.

The surveillance and control of ground traffic is ensured through Pilot's position report, traffic information and clearances, using radio voice communications between ATCOs and Flight Crews/Vehicle Drivers. The latter are supplemented by visual information in the form of lights, surface markings, and signs.

ATCOs control and/or surveillance will be improved by the use of such supplementary facilities and equipment as SMR, controllable taxiway lights, stopbars and local detectors *e.g.* inductions loops, intrusion alarm devices, etc.

Control may also include accompaniment by an escort who is in direct radio-communication with the control tower.

Visual aids are designed and published to allow the pilot to determine his position and follow the required route.

To determine the ability of the pilot to taxi in limited visibility conditions, the following facilities should be taken into account for suitability:

- Taxiway lighting
- Taxiway marking
- Location and characteristics of signs
- Availability of aerodrome charts with low visibility taxi routes

With regard to the control of ground movement of aircraft and vehicles the instructions from ATC shall be unambiguous (taxiway route/holding positions) so as for the position reports from Flight Crews / Vehicle Drivers .

6.3.2.7 Airport Capacity

As the visibility deteriorates towards the level associated to LVP the runwy capacity is progressively decreased.

The traffic capacity that can be sustained during LVP depends largely on the ground movement procedures in force, but they have always, as a bottom limit, the applicable spacing between successive approaches created to protect the critical and sensitive areas for the landing aids.

6.3.2.8 Separation minima

The surveillance of the aerodrome is performed visually by the ground controller; the operational procedures on the surface of an aerodrome depend mainly on pilots, ATCOs and vehicle drivers using visual observation coherent with the concept of see and be seen.

There is no spacing technique to apply between taxiing aircraft, which approaches the efficiency of that of pilots in good visibility. It follows that is the interest of both ATC and pilots to leave responsibility for collision avoidance with the pilots while conditions are such that they can safely fulfil the function; this function shall be integrated with traffic information and clearances given by the controller containing type, distance and relative position of the preceding/crossing conflicting traffic.

In the absence of non-visual guidance for taxing, the lower limit of aircraft surface operation must be the visibility below which the pilot is unable to taxi by visual reference.

This limit will depend on a number of factors such as aerodrome facilities, visual aids, cockpit view, familiarity with the area, etc.

When visibility decreases to the low levels, first Flight Crews are not able to avoid each other (Visibility Condition 3) and then not able to taxi on the airport surface (Visibility Condition 4).At this stage ATC must assume the responsibility for providing lateral and longitudinal spacing along the taxiway.

There are no aircraft separation minima defined in terms of lateral or longitudinal distances on the airport surface. This is achieved by setting up procedural control operations as explained in the ICAO SMGCS manual ([3] section 4.5 especially 4.5.4 to 4.5.18). The objective is to set up blocks of taxiways considered "strategically" separated from each other into which, only one aircraft at a time is allowed to taxi.

According to ICAO PANS-ATM the longitudinal and lateral separations on taxiway during low visibility operations shall be as specified for each particular aerodrome by the appropriate ATS Authority.. This separation shall take into account the characteristics of the aids available for surveillance and control of ground traffic, the complexity of the aerodrome layout, etc.

6.3.3 Transfer of Responsibility for Control

6.3.3.1 Coordination between a unit providing approach control service and a unit providing aerodrome control service

Note: Relevant paragraphs of this section are not applicable when two or more parts of the air traffic control service are provided by one unit, since, in such case, no transfer of responsibility is necessary in respect of the provision of such parts of the service.

Place or time of transfer

Between a unit providing approach control service and a unit providing aerodrome control service, the responsibility for the control of an aircraft shall be transferred from one air traffic control unit to another as follows:

1. Arriving aircraft. The responsibility for the control of an aircraft approaching to land shall be transferred from the unit providing approach control service to the unit providing aerodrome control service, when the aircraft:
   a) Is in the vicinity of the aerodrome, and
      1) It is considered that approach and landing will be completed in visual reference to the ground, or
      2) Has reached uninterrupted visual meteorological conditions, or
   b) Is at a prescribed point or level, or
   c) Has landed: for example, in case of very low visibility or emergency, the approach can keep in contact the aircraft until landing, a coordination previous to its landing is made with the tower to check the runway occupancy.

In case of GCA PAR. RWY "ownership" authorization is provided by CDN (voice or electronically) as specified in letters of agreement or ATS unit instructions.

Note: Even though there is an approach control office, control of certain flights may be transferred directly from an area control centre to an aerodrome control tower and vice versa, by prior arrangement between the units concerned for the relevant part of approach control service to be provided by the area control centre or the aerodrome control tower, as applicable.

Departing aircraft. The responsibility for control of a departing aircraft shall be transferred from the unit providing aerodrome control service to the unit providing approach control service as specified in letters of agreement or ATS unit instructions;

1) Immediately after the aircraft is airborne, or
2) When the aircraft is at a prescribed point or level,

Co-ordination of transfer

Responsibility for control of an aircraft shall not be transferred from one air traffic control unit to another without the consent of the accepting control unit.

1. The transferring control unit shall communicate to the accepting control unit the appropriate parts of the current flight plan and any control information pertinent to the transfer requested.
   - Where transfer of control is to be effected using radar data, the control information pertinent to the transfer shall include information regarding the position and, if required, the track and speed of the aircraft, as observed by radar immediately prior to the transfer.
   - Where transfer of control is to be effected using ADS data, the control information pertinent to the transfer shall include the four-dimensional position and other information as necessary.
2. The accepting control unit shall:
   - Indicate its ability to accept control of the aircraft on the terms specified by the transferring control unit, unless by prior agreement between the two units concerned, the absence of any such indication is understood to signify acceptance of the terms specified, or indicate any necessary changes thereto; and
   - Specify any other information or clearance for a subsequent portion of the flight, which it requires the aircraft to have at the time of transfer.
3. The accepting control unit shall notify the transferring control unit when it has established two-way voice and/or data link communications with and assumed control of the aircraft concerned, unless otherwise specified. Silent hand-over enabled by existing LoA is the most common practice for the airports considered.

Exchange of movement and control data

1. An aerodrome control tower shall keep the unit providing approach control service promptly advised of pertinent data on relevant controlled traffic such as:
   - Arrival and departure times
   - When required, statement that the first aircraft in an approach sequence is in communication with and is sighted by the aerodrome control tower, and that reasonable assurance exists that a landing can be accomplished.
   - All available information relating to overdue or unreported aircraft
   - Information concerning missed approaches
   - Information concerning aircraft that constitute essential local traffic to aircraft under the control of the unit providing approach control service

2. The unit providing approach control service shall keep the aerodrome control tower promptly advised of pertinent data on controlled traffic such as:
   - Estimated time and proposed level of arriving aircraft over the aerodrome, at least fifteen minutes prior to estimated arrival;
   - When required, a statement that an aircraft has been instructed to contact the aerodrome control tower and that control shall be assumed by that unit;
   - Anticipated delay to departing traffic due to congestion.

This information is automatically issued by FDPS and RDPS.

6.3.3.2 Coordination between control positions within the same unit

Appropriate flight plan and control information shall be exchanged between control positions within the same air traffic control unit, in respect of:

- All aircraft for which responsibility for control will be transferred from one control position to another
- Aircraft operating in such close proximity to the boundary between control sectors that control of traffic within an adjacent sector may be affected
- All aircraft for which responsibility for control has been delegated by a procedural controller to a radar controller, as well as other aircraft affected

According to the ICAO documentation, these are the general rules for control handover. However, additional procedures exist at airports depending on how the functions of an aerodrome control tower are divided into different control or working position. So, coordination procedures should be customized for each airport.

6.4 CNS / ATM Systems

6.4.1 CNS coverage

6.4.1.1 Communication

VHF voice communication is the main communication means for controlling aircraft and vehicles. Dedicated channels are used to support TWR communications with aircraft and vehicles. Multiple channels are usually used for controlling different parts of the airport. In addition to voice communications, visual aids such as taxiway lights, intermediate holding positions and stopbars are also used to communicate information that is essential to support surface movements.

Data link technology is used as well to send departure clearances (DCL) and/or ATIS messages (DATIS)

6.4.1.2 Navigation

Usually airports have several navigation means installed, including VOR, NDB, VOR-DME and ILS. None of these aids is of any significance to surface navigation excepted ILS LLZ guided take-off. Visual aids used to support movements on the airport include signs, markings, and lights. There are different types and configurations of taxiway and runway lights, including centreline and edge lights and stop bars.

6.4.1.3 Surveillance

For airborne aircraft (i.e. aircraft taking off and landing), the surveillance tool for aerodrome controllers is primary and secondary radar supporting visual methods. Radar data is used by TWR for information purposes to assess distances and, in most airports, for applying separation between aircraft.

Surface movement surveillance is currently based on visual observations and the use of Surface Movement Radar (SMR) data. Supported by other systems (e.g. MLAT, ADS/B, vehicle tracking systems, etc.) and/or operator inputs, some SMR systems are capable of providing, in a display label, the identity of aircraft and vehicles manoeuvring on the airport surface.

6.4.2 Planning systems

This paragraph gives a general overview on planning issues for ground traffic management.

6.4.2.1 Planning of Aircraft Surface Movements

Presently at European airports no operational planning systems are in use for the planning of individual aircraft surface movements.

Instead the planning of aircraft surface movements is based on mental processes of the different controllers, who are responsible throughout the dispatch cycle for inbound and outbound flights at the airport.

According to the task of the respective control position, i.e. Aerodrome, Ground and Apron, each controller plans the necessary operations individually, taking into account several factors and constraints:

- Flight plan information, stand allocation plan, ATFM regulation (CFMU slots)
- Operational status of an aircraft and departure clearance issued (contains runway allocated, SID, target off-block time)
- Airport configuration, e.g. runways in use, taxiways available
- Actual traffic situation
- Aircraft current position and state vector, allocated stand and taxi route
- Weather and visibility conditions
- Knowledge and personal experience concerning the duration of procedures
- Coordination with and handover to other control positions
- Standard taxi routes

The results of the mental planning processes for a given control position are mainly:

- The overall course of operations for an individual aircraft within the area of responsibility
- The actual (next) operation to be performed by an individual aircraft
- The sequence, in which several aircraft shall perform a specific operation
- The time at which an individual aircraft operation must take place or begin
- The time at which an operation should be finished.

The quality of the mental planning results depends largely on:

- The qualification and personal experience of a controller
- The availability and quality of information on which the decisions are based
- The actual workload and personal stress situation.

6.4.2.2 Airport Resource Planning and Management Systems

Several tools to assist the management of airport resources and to allow the communication between airport operations and other actors, both airports – related and other external actors - support the airport operation.

Generally, at all airports, there is a support system for airport resource allocation (such as checking counters, baggage belts or embarking lounges). It optimises airport resources and it solves tactical conflicts minimising planning deviations.

Allocation criteria are defined by means of different “strategies” which group the set of rules for the resource allocation that apply to different environment conditions. The characterisation of other elements that participate in the processes, such as handling agents, airlines, or aircraft, complements these criteria.

Those systems allocate resources such as parking stands, boarding gates, arrival lounges, baggage belts, and checking counters. In addition, they usually estimate the need for other airport resources related to the terminal building. Stands are the only airport resource relevant to EMMA managed by those tools.

It should be noticed that those systems receive arrival and departure time estimations from the ATC system -flight data processing system- that are also used for allocating the available resources.

Finally, airport resource planning systems are applicable to the strategic and tactical phases of airport operations. Moreover, they generally support later analysis of airport operations and their relationship with resource allocation to allow strategy refinement.

Summarising the actual situation concerning how ground traffic management is performed today, the following can be said:

- No centralized planning authority exists, who plans the overall turn of an aircraft on the ground
- The traffic flow is managed piecewise by Aerodrome Control, Ground Control, and Apron Control. Frequently there is lack of coordination between the different control positions and also different interest of involved parties.

The today transfer of planning and other information is realised by passing printed flight stripes, by telephone, by access to flight plan server or even not available.

In order to overcome the limitations of ground traffic management as depicted above, and in order to gain noticeable improvements, centralised planning functions have to be identified, realised and introduced, which plan the traffic as a whole, and assist all involved parties with consistent information.

Providing a safe, timely, and efficient traffic flow on ground of the airport requires making optimal use of the key resources, which are the limiting elements for the traffic flow within the manoeuvring area of the airport:

- The runways and runway exits
- The gates
- The taxiway system as the connecting element between runways and parking positions.

6.4.2.3 Airline and Aircraft Aspects

Airline operations are heavily dependant and interconnected with planning systems of airports and ATS providers. As it is fact today that stand/position allocation planning for inbound flights is connected to airlines planning systems, this will be the case to a greater extent for higher level of A-SMGCS. Airliner Users, e.g. major airlines serving their hubs, which are under their ownership, require planning authority for all operations in- and outbound.

In order to optimise the overall efficiency, prioritising or delaying of individual flights will be required. Such short term planning must be interconnected with A-SMGCS planning systems.

6.4.3 System failure fallback

Different system(s) degradation possibilities and stages can be identified:

- Communication
  - Total communication failure (voice and data)
  - Partial communication failure (voice and data)
- Navigation
  - Total or partial loss of lighting system

- Total or partial loss of visual aids for navigation including docking guidance systems
- Total or partial failure of on-board equipment

- Surveillance
  - Total or partial loss of automated surveillance system
  - Total loss of surveillance data
  - Partial loss of surveillance data (either TAR, SMR, MLAT, ADS-B or gap filler)

The following sections aim at presenting the fallbacks means for communication and surveillance failures.

6.4.3.1 Communication:

- **Communication failure. (On-board equipment)**

Once a communication failure is detected by ATS, the following procedure will be carried out:

- Radar controller will try to know if airplane is able to receive the information given by ordering certain manoeuvring that could be identified by radar or by another way in order to acknowledge receipt. If a negative answer is obtained radar controller will make sure to keep separation minima between the airplane with the communication failure and the others.
- Just after ATS dependencies identifies the communication failure, every information about the previous procedure carried out will be transmitted in available frequencies in which all the airplanes involved could be aware about the present situation. Even navigation aids frequencies could be used.

Another procedure in order to face a total communication failure is based on the use of visual signals: (at airports)

- Flashing green lights: It indicates clearance to cross the landing area or to get the taxiway
- Red fixed signal: It indicates stop
- Flashing red lights: It indicates to leave the landing area or the taxiway. Be aware of other aircraft.
- Flashing white lights: It indicates to return to the starting point on the aerodrome and leave the manoeuvring area.

Any flashing light in a runway or in a taxiway will order to leave a runway or taxiway and observe the tower waiting for a luminous signal.

- **Ground radio failure**

In the event of complete failure of the ground radio equipment used for radar control, the radar controller shall, unless able to continue to provide the radar service by means of other available communications channels, proceed as “radar equipment failure”.

When these provisions are not applicable, the controller shall:

- Without delay inform all adjacent control positions or ATC units, as applicable, of the failure
- Appraise such positions or units of the current traffic situation;
- Request their assistance, in respect of aircraft which may establish communication with those positions or units, in establishing radar or non radar separation between and maintaining control of such aircraft; and
- Instruct adjacent control positions or ATC units to hold or reroute all controlled flights outside the area of responsibility of the position or ATC unit that has experienced the failure until such time that the provision of normal services can be resumed

In order to reduce the impact of complete ground radio equipment failure on the safety of air traffic, the appropriate ATS authority should establish contingency procedures to be followed by control positions and ATC units in the event of such failures.

6.4.3.2 Surveillance

- **Radar equipment failure**

In the event of complete failure of the radar equipment except for air-ground communications, the controller shall apply the procedures described in ICAO PANS-ATM section 7.1.1.2. When controllers have not visual contact with aircraft, the section 7.10.1 applies.

6.5 Traffic characteristics

6.5.1 Traffic / Schedule Demand

Air traffic creates demand for runway availability, throughput and occupancy, and gate availability at airports. A major objective of the services described in this document is to better accommodate this demand while at the same time enhance the safety of operations.

6.5.1.1 Throughput

The maximum throughput of an airport depends on:

- Airport complexity
- Weather conditions
- Arrival and departure procedures (noise abatement procedures)
- Departure flight procedures
- TWR manning
- Scope of implementation of aerodrome CNS equipment
- ATC operational procedures
- Level of ATC automation
- Restrictions concerning constructive activities on the airport.
- Level of flight crew preparation and familiarisation with the airport
- Traffic mix

It is usually measured in movements per hour, or arrival /departure per hours with max figures per lower duration, e.g. max per 10 minutes.

6.5.1.2 Runway Occupancy

Runway occupancy times for landing aircraft vary largely depending on aircraft type, runway and taxiway configuration and traffic characteristics. Time interval between two departing aircraft ranges from 60 to 120 seconds. For wake turbulence reasons, this interval may be extended to 180 s after a heavy category aircraft. Time interval, moreover, may be extended also considering Standard Departure Routes, weather conditions, runway layout constraints, aircraft speed ATC Organisation, rating of aerodrome controllers (non inclusive list).

For purposes of inspections and maintenance, vehicles operate on the runways approximately one hour per runway per day. Such operations are co-ordinated with aircraft movements by aerodrome controllers, and the effect on runway throughput is not neutral.

6.5.1.3 Sector traffic density

ICAO (European Manual on A-SMGCS) has defined traffic density categories (regardless of visibility conditions) as follows:

- Light (L): Not greater than 15 take-off or landings per runway or typically less than 20 total aerodrome movements per hour;
- Medium (M): 16 to 25 take-off or landings per runway or typically between 20 to 35 total aerodrome movements per hour;
- Heavy (H): 26 take-off or landings per runway or more or typically more than 35 total aerodrome movements per hour.

6.5.2 Aircraft mix

6.5.2.1 Aircraft performances

6.5.2.1.1 Speed

A large spectrum of aircraft speeds will exist, i.e. from low performance to high performance piston/turboprop/jet aircraft that are authorised to operate on A-SMGCS equipped airports; the system must be capable of supporting operations with minimum and maximum speeds for aircraft on final approach, missed approach and runways, minimum and maximum speeds of aircraft on taxiways.

For speed mix refer to ICAO A-SMGCS Manual Chapter 2.6.4.1 and 4.1.8

6.5.2.1.2 Climb/descent rates

Depending on the individual performance capabilities of each aircraft climb and descent rates will vary considerably; this will be the case especially during final and missed approaches thus affecting the Runway Incursion Detection service.

6.5.2.1.3 Altitude

Generally altitude on final for low and high performance aircraft using a specific ILS will be identical; however during missed approaches significant differences between low and high performance aircraft will occur.

6.5.2.2 CNS equipment

Airborne equipment provided for A-SMGCS Level I and II services on board of revenue aircraft must comply with requirements set up for Mode S Enhanced Surveillance functionality effective from 31st March 2005. Modifications will be mandated for transponders - if not already performed, i.e. ICAO Level II Mode S transponder compliant with Annex 10 Amendment 77 to enable the down linking of aircraft parameters to the ground. In addition wiring changes for aircraft systems might be necessary to enable the down linking of aircraft parameters such as indicated air speed/Mach number, ground speed, magnetic heading, position and others.

6.5.3 Vehicle mix

Vehicles not authorised to operate on the manoeuvring area can be expected on the manoeuvring area in conjunction with an authorised vehicle taking the lead in a convoy.

Vehicles authorised to operate on the manoeuvring area can be expected to operate not only on the dedicated taxiway and runway system, but also on the unhardened areas like grass strips.

6.5.3.1 Vehicle performances

6.5.3.1.1 Speed

No speed restrictions apply for vehicles on the manoeuvring area. The maximum speed allowed for ground vehicles on aprons is limited according to the applicable rules for the apron. In general this is either 30 km/h or 40 km/h. Speed limits are not applicable for emergency vehicles.

6.5.3.2 CNS equipment

6.5.3.2.1 Communication

Vehicles that only operate in the apron area are not required to be radio equipped. Vehicles that are authorised to operate on the manoeuvring area must be radio equipped to communicate requests and clearances or monitor only the frequency for free range vehicles with the TWR.

6.5.3.2.2 Navigation

When navigating on the airport, the vehicle drivers rely on visual observations and aids (e.g. signs and lights) to guide them along their assigned routes and to identify intersections and holding points. The vehicle driver monitors surrounding traffic to prevent collision by visual means and traffic information provided by the air traffic controller.

A printed airport plan could be available in all vehicles indicating the boundaries of the manoeuvring area and the runway crossing points.

6.5.3.2.3 Surveillance

Unless specifically exempted, vehicles are fitted with appropriate marking and lighting for easier perceptibility.

7 Abbreviations

ABBREVIATION	Long Name
ACC	Approach Control Centre
ADS-B	Automatic Dependant Surveillance - Broadcast
ADS-B	Automatic Dependent Surveillance Broadcast
AEA	Association of European Airlines
AIP	Aeronautical Information Publication
AMAN	Arrival MANager
ANSP	Air Navigation Services Providers
AO	Aircraft Operator
APN	Apron
APP	Approach control
ASMGCS	Advanced Surface Movement Guidance Control System
ATCO	ATC controller
ATFM	Air Traffic Flow management
ATIS	Automatic Terminal Information System
ATM	Air Traffic Management
ATS	Air Traffic Services
ATSP	Air Traffic Service Provider
ATWR	Apron Tower
BFE	Buyer Furnished Equipment
CDG	Charles De Gaulle
CDN	Coordination
CFMU	Central Flow Management Unit
CNS	Communication Navigation Surveillance
COP	Coordination Point
CTAS	Centre TRACON Automation System
CTOT	Calculated Take Off Time
CTR	Control Zone
DA	Descent Advisor
DGPS	Differential Global Positioning System
DMAN	Departure manager
DME	Distance Measuring Equipment
ECAC	European Civil Aviation Conference
EFS	Electronic Flight Stripe

ABBREVIATION	Long Name
EGNOS	European Geostationary Navigation Overlay Service
EMMA	European Airport Movement Management by A-SMGCS
EOBT	Estimated Off Block Time
ETA	Estimated Time Of Arrival
ETD	Estimated Time of Departure
FDPS	Flight Data Processing System
FRTT	Flight crew reaction time to ATC take-off clearance
GCA	Ground Controlled Approach
GH	Ground Handling
GND	Ground
HMI	Human Machine Interface
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LLZ	Localizer
LUPT	Line Up Time
LVO	Low Visibility Operation
LVP	Low Visibility Procedures
MLAT	Multilateration
MLS	Microwave Landing System
MTOT	Managed Take Off Time
NDB	Non Directional Radio Beacon
OSED	Operational System And Environment Description
PAR	Precision Approach Radar
RDPS	Radar Data Processing System
ROP	Runway Occupancy Planning
ROT	Runway Occupancy Time
ROTA	Arrival Runway Occupancy Time
ROTD	Departure Runway Occupancy Time
RTF	Radio Transmission Form
RVR	Runway Visual Range
RWY	Runway
SA	Situational Awareness
SID	Standard Instrument Departure route clearance

ABBREVIATION	Long Name
SLA	Service Level Agreement
SMAN	Surface Manager
SMGCS	Surface Movement Guidance Control System
SMR	Surface Movement Radar
SSR	Secondary Surveillance Radar
STD	Scheduled Time of Departure
TAR	Terminal Area Surveillance Area
TCAS	Traffic Collision And Avoidance System
TIS-B	Traffic Information Service Broadcast
TMA	Terminal Control Area
TOFT	Take Off Time
TRACON	Terminal Radar Approach Control
TWR	Tower
TWY	Taxiway
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omni-directional Radio Range (OMNI)
WAIT	Wait Time

8 Annex I

8.1 References

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References [4], [5], [6] and [7] are available on the following url:

http://www.eurocontrol.int/airports/projects/asmgcs/index.html

8.2 List of Figures

8.3 List of Tables

9 Annex II - Implementation proposal for Alert provided to flight crew

This annex aims at proposing a possible implementation of EMMA services that provides alerts to flight crew.

This section could be broken down as follow:

- Alert Description
- Runway Alerting Function
- Taxiway Alerting Function
- Traffic Conflict Detection

9.1 Alert Description

9.1.1 Presentation of alerts

When conflicts / infringements are detected by runway alerting function, taxiway alerting function or fixed obstacle avoidance function, an alert is presented to flight crew using visual and/or sound processes.

Visual processes consist of the provision of alert situation information: type and location of alert situation, identification of the airport feature causing the conflict.

Sound processes consist of a sound alert issued when the alert situation necessitates an immediate action. A sound process will always be associated with a visual process in order to provide the user with the information he needs to understand the situation.

9.1.2 Stages of alert

Different levels of severity for alert situations may be distinguished. To each level of severity may correspond a different alert stage.

Eurocontrol recommends two stages of alerts for A-SMGCS purpose. These two stages of alert are defined as follow:

- **Stage 1 alert** is used to inform the user that a situation, which is potentially dangerous, may occur, and he/she needs to be made aware. According to the situation, the user receiving a stage 1 alert may take a specific action to resolve the alert if needed. This is called **Information** step. The information step can be presented only with visual process (e.g. for the runway proximity function, to display to the flight crew the runway is entering) or with sound and visual processes.
- **Stage 2 alert** is used to inform the user that a critical situation is developing which needs immediate action. This is called **Alarm** step. The Alarm step is always presented by visual and sound processes, because of the critical situation.

In general, a stage 2 alert is preceded by a stage 1 alert in order to anticipate the conflicts / infringements. However, it is not systematic and depends on the scenario. Depending on the detected situation information will not necessarily be issued and the system will directly trigger an alarm.

However, the cockpit alerts are classified by Airbus according to their criticality in compliance with the following table:

Alert Level	A/C condition	Criteria	Attention-Getter (AG)	
			Visual AG	Aural AG
3	EMERGENCY Situation	Emergency operational or aircraft system conditions which require immediate corrective or compensatory action by the flight crew	Red	Voice or sound
2	ABNORMAL Situation	Abnormal operational or aircraft system conditions which require immediate flight crew awareness and subsequent corrective or compensatory flight crew action	Amber	Voice or sound
1	RECOGNITION Situation	Operational or aircraft system conditions which require flight crew awareness and may require flight crew action	Highlighted symbology (e.g. pulsing)	None
0	INFORMATION Situation	Operational or aircraft system conditions which require flight deck indication	None	None

The equivalence between Eurocontrol stages of alert and cockpit alert levels is provided in the following table:

Eurocontrol stages of alert		Cockpit alert levels	
Stage of alert	**Step**	**Alert level**	**Aircraft condition**
No equivalence		0	INFORMATION Situation
1	INFORMATION	1	RECOGNITION Situation
		2	ABNORMAL Situation
2	ALARM	3	EMERGENCY Situation

In the scope of this annex, the cockpit alerts definition will be used.

9.2 Runway alerting function

9.2.1 State of the art

Currently, the control of the aerodrome is performed by the ground controller. The operational procedures on the surface of an aerodrome depend on pilots, air traffic controllers, and vehicle drivers using visual observation of the location of the aircraft and vehicles in order to estimate their respective relative positions and the associated risk of collision.

The management of movements on the aerodrome surface is manually performed by controllers by giving instructions to pilots and drivers through R/T messages or manually operated stop bars and taxiway lights. Pilots and vehicle drivers rely on visual aids (lighting, signage, and markings) and on paper charts to provide them with cues along their assigned routes and to identify intersections and holding points issued by the controller.

9.2.2 Runway proximity function

The intention of this function is to inform the flight crew that they are directly heading towards a runway and are about to enter it, i.e. that they are on a taxiway that:

- Either leads to a runway
- Or intersects a runway

The information will be displayed on the screen, in a form of a pulsating text message in the centre of the screen highlighting the designator of the active runway (e.g. 25L), and with the runway flashing on the screen. Additionally, for RECOGNITION type alerts, the corresponding runway could be highlighted or displayed in a different colour.

Depending on the distance to the runway and the associated holding position, this information will be of the INFORMATION/RECOGNITION type.

If the flight crew has misunderstood an ATC clearance, providing them with information on the runway they are about to enter could represent valuable information and feedback, thus reducing the stress linked to the perception of a Runway Incursion Alert.

Moreover, if there are several possibilities to turn on other taxiways before the current taxiway leads the aircraft onto the runway, and as it is difficult to anticipate flight crew intentions, the risk of false and nuisance alerts is far too high. Therefore, the INFORMATION/RECOGNITION levels are used in this function.

9.2.2.1 Taxi out

Accuracy and operational value of this function can be increased if:

- Runway operating directions & visibility (LVP or not), which pilots can find out by listening to ATIS or inquire from ATC,
- Departure runway (including operating direction)[37] and
- Runway status (default active, not cleared) for all runways

can be entered/made known interactively to the system via the taxi display HMI. Definition of departure runway independent of clearance status has the advantage that all levels of alerts can be handled differently.

Then the flight crew can be provided with timely advisories that they are:

- Taxiing towards the wrong runway altogether or
- Taxiing towards the wrong end of the assigned departure runway,

which can prevent line-up in the wrong direction at a very early stage.

9.2.2.2 Taxi back

Accuracy and operational value of this function can be increased if

- Landing runway (including operating direction)[38]
- Runway status (default active, not cleared)
- Arrival gate

can be entered/made known interactively to the system via the taxi display HMI. Immediately after the aircraft leaves the landing runway, its status changes to “not cleared”, as the aircraft might have to cross it again to get to the gate.

[37] This information could also be retrieved from the FMS
[38] This information could also be retrieved from the FMS

Then the flight crew can be provided with timely advisories that they are

- Taxiing towards the wrong gate, i.e. taxiing away from the assigned gate

9.2.3 Runway incursion alerting function description

The runway incursion alerting function provides an automated control service to the flight crew. This service detects the conflicts / infringements on the runway caused by the own aircraft.

For each conflict / infringement detected, the runway incursion alerting function provides an appropriate alert to flight crew.

This function gives assistance to the flight crew in their tasks by:

- **Anticipating potential conflicts**
- **Detecting conflicts**

The runway incursion alerting function primarily intends to contribute to operations as a safety net, preventing hazards resulting from pilot deviations or from operational errors or deviations. For the integrated solution, a connection to the auto brake system should be considered.

9.2.3.1 Protection areas

One potential solution to detect conflicts / infringements is to define virtual “protection areas” around runways, each corresponding to a certain level of alert severity.

As an example a conflict / infringement is detected when the own aircraft crosses the runway protection area boundary.

The form and size of the protection areas may vary depending on airport layout and ATC procedures.

The runway protection area is composed of two boundaries:

- A ground boundary to detect infringements on the surface
- An air boundary to detect approaches from the wrong direction

The boundaries of the runway protection area must be as close as possible to the runway to avoid nuisance alerts, but must be carefully determined to allow time for immediate action / reaction in order to prevent own ship from entering the runway after a potential hazard has been detected.

9.2.3.2 Ground boundary

9.2.3.2.1 Dynamic ground boundary

In order to prevent conflict infringements on the runway as far as possible and to anticipate them, a dynamic ground boundary is provided all around the runway, taking in account the speed and heading of each aircraft. Indeed, for most operations, the protection area shall be focussed on speed and heading of each aircraft and the runway alert function shall provide information to the flight crew that is about to enter a runway. This step of anticipation is particularly recommended by Airbus pilots in order to avoid as far as possible unnecessary alerts.

The dynamic boundary can be obtained by scaling the static ground boundary (see next section) as a function of a/c speed. Alternatively, the rate with which the aircraft approaches the static boundaries could be used as a measure. Another similar way of achieving this could be the estimation of the braking distance to ground speed zero, which could be calculated dynamically and compared to the distance to the applicable taxiway holding position.

9.2.3.2.2 Static ground boundary

In addition to the dynamic ground boundary, an “ultimate” static ground boundary must be defined in order to prevent runway incursion.

The length of the static ground boundary must at least include the runway strip. The width could be defined and differ according to the meteorological conditions, e.g. Non-LVP, LVP.

As an example based on today ILS holding positions:

- In Non-LVP: ground boundary defined by Cat I holding position
- In LVP: ground boundary defined by Cat II / III holding position

This static ground boundary will be used for both alerts stages.

Technically, the two protection areas can be obtained by connecting the holding positions and stop bars around the runway.

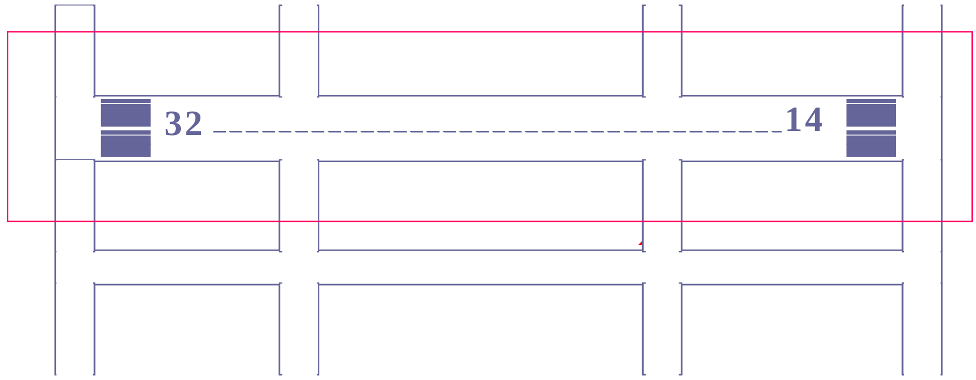


Figure 9-1 - Ground boundary of runway protection area

N.B: In order to avoid unnecessary alerts, current systems wait until the aircraft / vehicle has crossed the boundary.

9.2.3.3 Air boundary

The air boundary is defined as a flight time to threshold and would take into account two stages of alert, Abnormal situation and Emergency situation, as well as the meteorological conditions:

- Non-LVP: Prediction around T1 = 30’’, Alert around T2 = 15’’
- LVP: Prediction around T1 = 45’’, Alert around T2 = 30’’

To comply with [7] (A-SMGCS level 2 services to controller) these times of the two alert stages outlined above should be configurable, depending upon optimisation at the aerodrome.

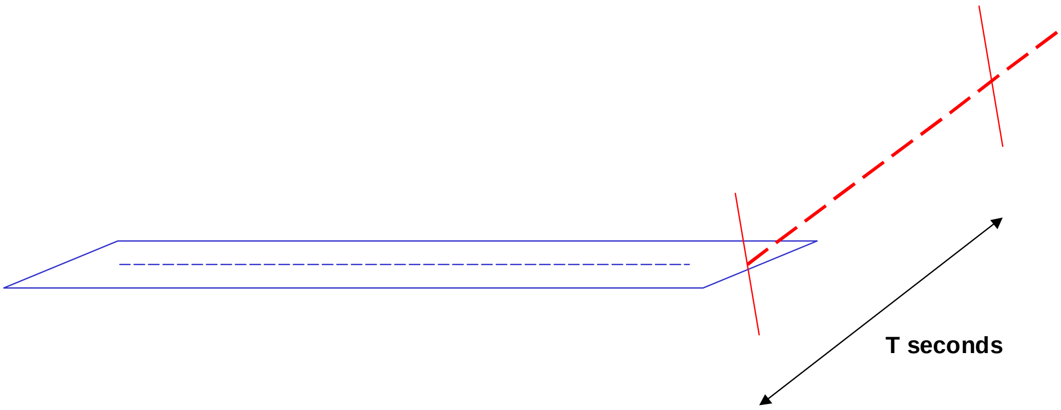


Figure 9-2 - Air boundary of runway protection area

9.2.3.4 Scope of Conflicts/ infringements on runway

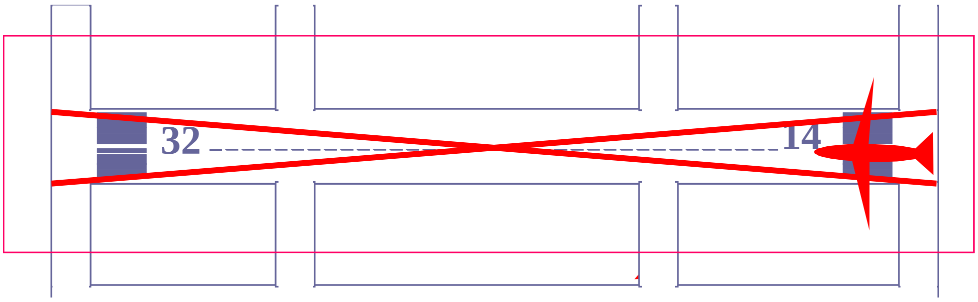
The runway incursion alerting function will detect a set of conflicts / infringement cases that are described in the following sections.

9.2.3.5 Conflicts / infringements involving the aircraft alone

In some particular cases, it is possible to detect unauthorised aircraft by using the status of the runway, for instance when the runway is closed, or when the aircraft does not respect the runway orientation.

Aircraft proceeding to a closed runway will trigger the following alerts:

- **Aircraft lining-up or taking-off** ➔ EMERGENCY or ABNORMAL

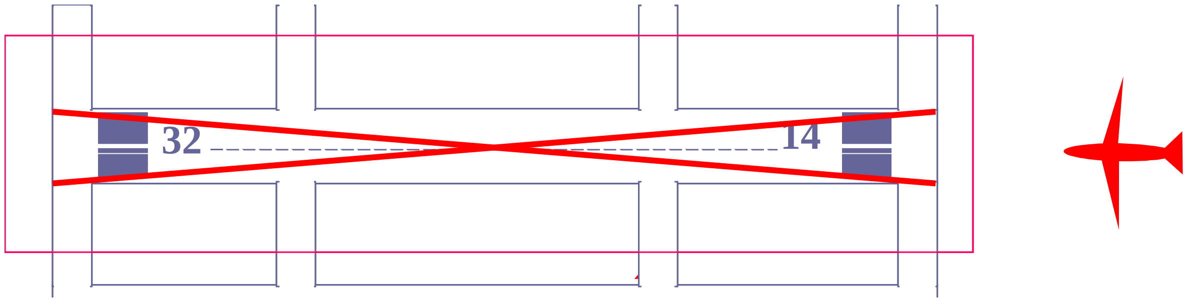


The alert level depends on the exact nature of the "closing". If the runway can still be used for taxiing, it shall be used like a taxiway, and the function preventing take-offs from a taxiway takes care of the situation.

If the runway is completely closed, there shall be a caution alert (ABNORMAL) as soon as the CAT II/III holding positions are crossed, and a warning alert (EMERGENCY) as soon as the inner CAT I holding positions are crossed.

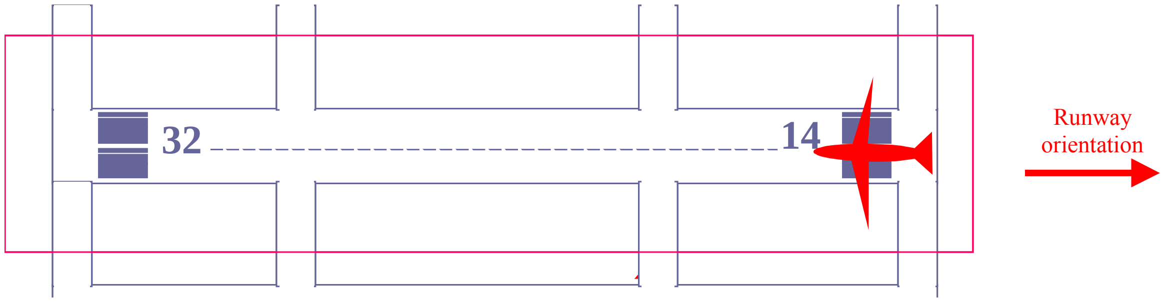
Rationale: The risk of substantial damage and fatalities is too high. There could be big holes, construction equipment like bulldozers and cranes anywhere on the runway surface. The a/c should be prevented from entering the runway altogether if it is completely closed. If the alert is raised only when the a/c is lining up or setting take-off power, it could be too late already.

- **Arriving aircraft** (< T1 from threshold) ➔ ABNORMAL
- **Arriving aircraft** (< T2 from threshold) ➔ EMERGENCY



Aircraft proceeding to a runway in the wrong direction will trigger the following alerts:

- **Aircraft arriving** on the runway in the wrong direction (< T1 from threshold) ➔ ABNORMAL
- **Aircraft arriving** on the runway in the wrong direction (< T2 from threshold) ➔ EMERGENCY
- **Aircraft lining-up** or taking off in the wrong direction ➔ EMERGENCY



There shall be a caution alert (ABNORMAL) as soon as the CAT II/III holding positions are crossed, and a warning alert (EMERGENCY) as soon as the inner CAT I holding positions are crossed.

In order to avoid nuisance alerts, the runway protection area must be carefully defined when runway is also used for other purposes such as crossing runway, or taxiing. This is why additional runway information like e.g. clearance, usage for arrival/departure, closure etc. is required.

9.3 Taxiway alerting function

9.3.1 State of the art

9.3.1.1 Outbound flight

When ready to taxi the pilot will request taxi instruction from ground, which includes the routing from the parking position normally to the holding position at the runway.

There may be operational conditions, which require the aircraft to report its position on the manoeuvring (e.g. before crossing another active runway or taxiway intersection).

9.3.1.2 Inbound flight

After landing, taxi instructions on where to exit the runway are delivered and the pilot is requested to contact ground upon vacating the runway for taxi instructions to the Apron area.

On the way to the Apron area, the pilot may be provided with gate/stand information where such regulation between air traffic control and the airport authority have been agreed to, and the aircraft will subsequently be picked up by a follow-me car at a position between the Manoeuvring area and the Apron area.

9.3.1.3 Scope on ground control

At that time flight crew shall taxi the aircraft visually, following the “see and be seen” principle as well as instructions and with regards to traffic information provided by air traffic control.

At airport with a high level of complexity, this results in a significant increase in both pilot and controller workload that could lead to the introduction of an important level of uncertainty and stress. In order to maintain the appropriate level of safety, constraining rules have to be enforced thus reducing the airport capacity and throughput. For example, in low visibility conditions aircraft could be suggested to progressive taxi instruction which limit the authorised progression of an aircraft to the next segment of its itinerary (most of the time to the next intersection). It inevitably induces extra R/T transmission for the pilot to return its position to the controller, but this is the only way to have the insurance to maintain a good level of safety during surface operations.

There are no separation minima defined in terms of lateral or longitudinal distances on the airport surface. In good visibility, conflict avoidance is based on visual principles ("see and be seen") and instructions and traffic information issued by ATC. There are restrictions on taxiways and aprons for low visibility conditions when the airport is operating in accordance with a dedicated set of rules referred to as Low Visibility Procedures (LVP). In such conditions, some airports apply restrictions. For instance, taxiways may be restricted to a specified number of simultaneous aircraft operations.

9.3.2 Taxi route conformance and taxiway compatibility functions

9.3.2.1 Overview

In order to overcome the limitations of ground traffic management as depicted above, and in order to gain noticeable improvements; automated taxi route conformance functions have to be identified, realised and introduced, which assist the flight crew during taxiing phase with harmonized and consistent information.

The aim of the taxi route conformance and taxiway compatibility functions function is to check the conformance of the taxi route aircraft the aircraft follows, with regard to the assigned route given by the controller (if any), and with regard to aircraft characteristics (size and weight).

The functions ensure that the aircraft follows the route assigned by the controller, and the function also prevents aircraft from turning where no corresponding taxi line exists (closed taxiway, one-way taxiways, roadways…).

Moreover, the functions check that the aircraft is entering a taxiway that is suitable due to weight, size, or aircraft type constraints. This point allows preventing, for instance, taxiway degradations by large aircraft. Two different cases should be envisaged:

- Compatibility checking all along the assigned route based on ATC datalink uploaded ground path,
- "Real time" computation when the aircraft is about to enter a non-compatible taxiway

These two qualities are useful especially to help for large aircraft taxi and in case of low visibility conditions. Indeed, the functions are providing electronic support to the flight crew to complement the out-of the window view independently of visibility conditions and allow the flight crew to maintain a good level of situational awareness.

The provision of taxi routes to the flight crew is done using a specific data link service which allows loading and verifying the taxi route. The taxi route shall be loaded directly using the data-link service. Alternatively, the flight crew should be provided with facilities to enter a route manually at airfields where this service is not available.

For arrivals, the availability of a data-link service allows providing taxi routes even before landing, however the limitation here is the capability to define a taxi route prior clearing the arrival runway because the runway exit is selected by the flight crew.

For Departures, the availability of a data-link service allows to provide taxi routes at any time prior to entering the movement area.

The main expected benefits with the taxi route conformance and taxiway compatibility functions are:

- **Reduce likelihood of navigation errors** on the aerodrome surface: the taxiway conformance function will provide an alert to the flight crew in case of wrong turns or use of non-assigned taxiways (due to weight or size constraints).
- **Reduce probability of miscommunication** and / or misunderstanding with respect to voice communication thanks to the data link.
- **Reduce the amount of voice traffic** on the radio channel as the number of “say again” and progressive taxi instructions
- **Remove the workload** for entering manually the taxi route

9.3.2.2 Alerts

The taxiway conformance function will provide alerts to the flight crew when the aircraft is entering a non-assigned taxiway or when it is entering a taxiway where it is not allowed to enter due to its characteristics (size or weight). Only one stage of alert is provided, the ABNORMAL alert level. The EMERGENCY level shall be restricted to hazardous scenarios (i.e. runway incursion).

9.3.3 Taxiway safety margin control function

9.3.3.1 Overview

The Taxiway safety margin control function checks that the aircraft is on the taxiway respecting the margins regarding the edges, and provides alerts when the aircraft is infringing these margins.

The Taxiway safety margin control function is providing electronic support to the flight crew to complement the out-of the window view independently of visibility conditions, and allows the flight crew to maintain a good level of situational awareness and to prevent any deviation from the taxiway strip.

The main expected benefits with the Taxiway safety margin control function are:

- **Increase taxi speed:** by providing an alert when the aircraft will not follow the taxiway guidance line, the taxi route conformance function will allow to increase taxi speed for aircraft, and thus increase the overall airport throughput.
- **Allow operation in zero visibility conditions**: the taxi route conformance function will allow the flight crew to follow the centreline of the taxiway within an acceptable margin in all visibility conditions. An alert will be provided to the flight crew to prevent conflicts/ infringements and navigation errors.

9.3.3.2 Alerts

The Taxiway safety margin control function will provide alerts to the flight crew when the aircraft is deviating from the taxiway centreline. Only the Recognition level is needed. The EMERGENCY level shall be restricted to hazardous scenarios (i.e. runway incursion).

9.3.4 Taxiway take-off alerting

9.3.4.1 Overview

This function aims to prevent take-offs from taxiway. Detection of an erroneously intended taxiway take-off has to occur as early as possible (e.g. when take off power is set, or when speed exceeds a particular value).

This function will be helpful for flight crew especially in LVP conditions, when the mistakes between runway and taxiways can occur.

9.3.4.2 Alerts

The taxiway take-off alerting function will provide alerts to the flight crew when the aircraft is taking off from a taxiway. Therefore, the flight crew will be alerted if:

- Take-off power or any power setting exceeding 90% N1 is set. => ABNORMAL warning level when power is set with parking brake on. EMERGENCY whenever parking brake is released.
- The acceleration and the derivative of the acceleration exceed 80% a_{TO} or 60% d/dt a_{TO} typical of this aircraft type => EMERGECY level alert.
- The ground speed exceeds the taxiway speed limit by more than 5 kts (=> ABNORMAL) or 15 kts (=> EMERGENCY) with dv/dt positive.

9.4 Fixed obstacle avoidance function

9.4.1 State of the art

Current situation for the surface movement is based primarily on the “see and be seen” principle for the flight crew to prevent the collisions with ground fixed obstacles on the airport area. However, fixed obstacles on airport, such as antennas, building, ground lights… present risks for aircraft during surface movements, especially for aircraft parts such as wingtips and tail, which are out of view for the flight crew.

In low visibility, the pilot can only refer to the controller’s warnings and instructions to be aware of any risk of deviation from the assigned route or risk of collision with a fixed obstacle. This implies a significant workload in controller and flight crew workload, due to the R/T transmissions to prevent collisions.

9.4.2 Fixed obstacle avoidance function description

The fixed obstacle avoidance function will provide the flight crew with alerts to prevent any collision between the aircraft and a fixed obstacle during airport surface movements.

An aircraft might unintentionally enter areas in which it is not authorised to operate, and where there is a risk of collision between the aircraft and a fixed obstacle. These situations may be potentially dangerous. The objective of the fixed obstacle avoidance function is to avoid potentially dangerous situations created by mistakes of the flight crew or due to low visibility conditions. A particular emphasis will be put on the critical parts of the aircraft, namely the wingtips and the tail. Indeed, these two parts are out of the flight crew field of view and present significant risk of collision with a fixed obstacle such as building or antennas for instance.

In order to complete its control task, the fixed obstacle avoidance function will address restricted area all around each fixed obstacle where the presence of an aircraft is unauthorised and hazardous. The perimeter of the restricted areas shall be done in order to prevent a collision of the fixed obstacle with any aircraft: thus, the restricted area must be defined regarding the size of the aircraft considered. The onboard function can use the data of the a/c it is installed in, this should be configured upon installation in the airframe. The aim of the fixed obstacle avoidance function will be to detect any intrusion of an aircraft into a restricted area.

The service provides an automatic ABNORMAL and EMERGENCY situation to flight crew entering an unauthorised area. Upon the EMERGENCY indication, the flight crew shall take the appropriate action to leave the unauthorised area.

9.5 Traffic Conflict Detection

In order to trigger the appropriate alerts to the flight crew, the position of the aircraft / vehicles should be analysed according to the set time-parameters, their relative speeds and positions when entering the runway protection area:

- Aircraft / vehicle
- Arrival / Arrival
- Arrival / Departure
- Departure / Departure
- Including aborted takes-off and go-around

Consideration should be given to the working methods of every airport and the local parameters like reduced separations on the runway when approved by the ATS authorities.

The following scenarios are recommended for A-SMGCS level III. They are based on ICAO rules and experience from existing A-SMGCS.

9.5.1 One Runway

Conflicts / infringements involving an aircraft and another aircraft / vehicle

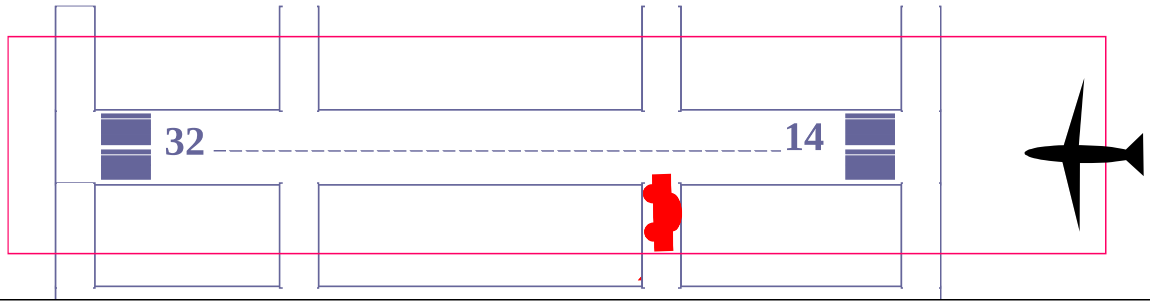
In order to trigger the appropriate alerts to the flight crew, the position of the aircraft / vehicles should be analysed according to the set time-parameters, their relative speeds and positions when entering the runway protection area:

- Aircraft / vehicle
- Arrival / Arrival
- Arrival / Departure
- Departure / Departure
- Including aborted takes-off and go-around

Consideration should be given to the working methods of every airport and the local parameters like reduced separations on the runway when approved by the ATS authorities.

The following scenarios are recommended for A-SMGCS level III. They are based on ICAO rules and experience from existing A-SMGCS. They will be assessed during the validation activities.

<u>A. Arriving Aircraft</u>

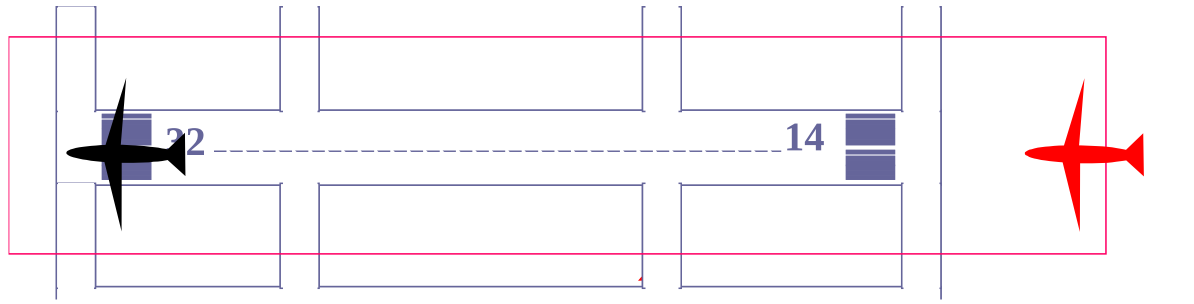
<table>
<tr><td rowspan="2">A.1</td><td>An aircraft / vehicle is on the runway protection area surface</td></tr>
<tr><td>The arriving aircraft is < T2 from threshold</td></tr>
<tr><td colspan="2">➔ ABNORMAL to the approaching arriving aircraft, until the arriving aircraft has passed the aircraft / vehicle (behind the arriving aircraft)
➔ EMERGENCY to the aircraft on the runway protection area (if any)

</td></tr>
</table>

A.2	There is a slower preceding departing aircraft which has not crossed the end of the runway-in-use or has not started a turn ([ICAO-4444] 7.9.1)
	The arriving aircraft is < T2 from threshold

➔ ABNORMAL for the approaching arriving aircraft

➔ ABNORMAL for the departing aircraft on the runway protection area

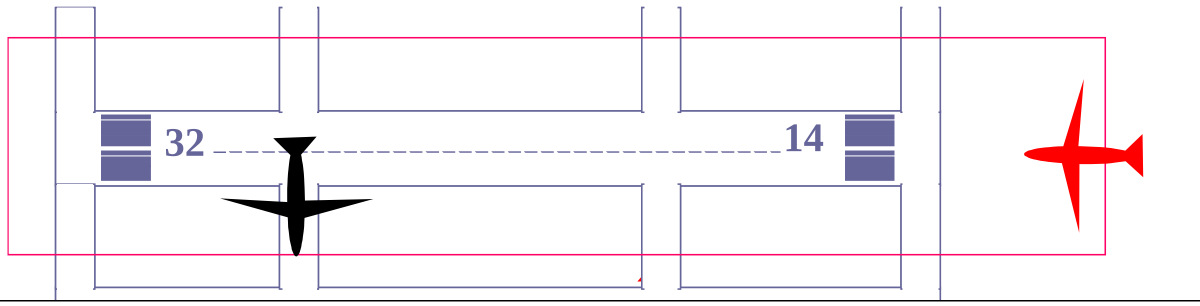
The system could be enhanced, as some existing systems do, by using the acceleration difference between both aircraft. It will allow to predict with more accuracy if there is a risk of collision or not, and so avoid unnecessary alerts.



A.3	There is a preceding arriving aircraft which has not cleared the runway <u>protection area</u> ([ICAO-4444] 7.9.1)
	The arriving aircraft is < T2 from threshold

➔ ABNORMAL for the approaching arriving aircraft

➔ EMERGENCY for the arriving aircraft on the runway protection area



B. Departing aircraft

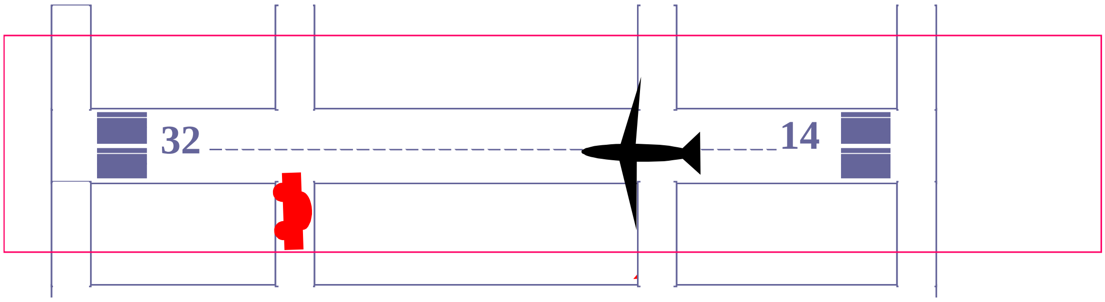
B.1	An aircraft or a vehicle is on the runway protection area surface and not behind the departing aircraft
	The departing aircraft is not yet taking-off (speed < 50 knots)

➔ ABNORMAL for the departing aircraft

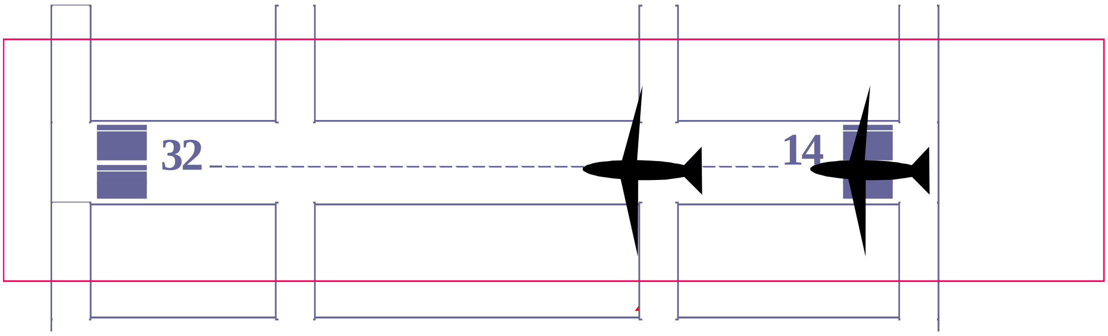
➔ ABNORMAL for the other aircraft (if any)

B.2	An aircraft or a vehicle is on the runway protection area surface and not behind the departing aircraft	
	The departing aircraft is taking-off (speed > 50 knots)	

➔ ABNORMAL for the departing aircraft
➔ EMERGENCY for the other aircraft (if any)



If multiple line-ups are applied, the system shall trigger an EMERGENCY for the aircraft that is behind, only if it has started its take-off and not when it is lining-up. The use of ABNORMAL for both aircraft in this case is left to local decision.



9.5.2 Two Runways

9.5.2.1 Parallel or converging runways

When operations are conducted on two parallel or converging runways, the only incursion hazard happens if one aircraft enters the protection area of the other runway while this one is engaged.

In order to avoid this situation, the A-SMGCS should analyse the position of the aircraft / vehicle according to the protection area of the active runway.

A design encompassing both runways in a large protection area would create too high a number of unnecessary warnings, especially when conducting simultaneous operations.

For that reason, each runway will be considered with its own protection area, and therefore two parallel or converging runways will be considered as two individual runways.

At most major airports the distance between the runways centrelines is such that the runway protection areas will not overlap.

Nevertheless, in order to avoid unwanted warnings, consideration should be given to the layout of the taxiways / runways (see ICAO Annex 10) when deciding about the parameters for the ground boundaries of the runway protection areas.

The position of the aircraft / vehicle will be analysed according to the protection areas of both runways then depending on the mode of operations (mixed or segregated) the A-SMGCS will issue, if need be, the ABNORMAL or/and EMERGENCY warnings already defined for the same configuration (landing or taking-off aircraft) for the one-runway scenarios.

In a further step, as an improvement, the analysis could be based on the predicted position of the aircraft / vehicle instead of its actual position.

9.5.2.2 Intersecting runways

9.5.2.2.1 Introduction

Even though there are no standard operating procedures for simultaneous operations [39]on intersecting runways, it is possible to identify rules for detecting conflicts on intersecting runways.

Although the only incursion hazard happens if one aircraft enters the protection area of the other runway while this one is engaged (see single runway cases), intersecting runways create an additional risk of collision at their intersection between two aircraft arriving or departing on both runways simultaneously.

In order to avoid this critical situation, the A-SMGCS will analyse the position of the aircraft / vehicle according to each runway protection area as in the single runway case and it will anticipate a conflict between two aircraft that could occur in the common part of the runways protection volumes before EITHER of the aircraft enters it. These rules of detection do not apply to vehicles but only to aircraft, especially when they are converging on the runway intersection. These rules of detection are defined hereafter.

9.5.2.2.2 Time To Threshold

It could be required to use Time To Threshold T1 and T2 different from those defined in section 9.5.1. We will call them Intersecting Runways Time To Threshold IRT1 and IRT2. They could be defined as following:

- Long final: Aircraft on final between IRT1 and IRT2;
- Short final: Aircraft on final between IRT2 and Threshold over-flight;

9.5.2.2.3 IR1: 1 aircraft is lining up

1 Line up + 1 Line up => ABNORMAL for both aircraft;

1 Line up + 1 Take off => ABNORMAL for both aircraft;

1 Line up + 1 Landing => ABNORMAL for both aircraft;

1 Line up + 1 Long final => No alert for both aircraft;

1 Line up + 1 Short final => ABNORMAL for both aircraft;

9.5.2.2.4 IR2: Simultaneous Take off & Landing

The following cases apply only when both aircraft are converging to the runways intersection.

1 Take off + 1 Take off + converging => EMERGENCY for both aircraft;

1 Take off + 1 Landing + converging => EMERGENCY for both aircraft;

1 Landing + 1 Landing + converging => EMERGENCY for both aircraft.

9.5.2.2.5 IR3: Simultaneous Finals

1 Long final + 1 Long final => ABNORMAL for both aircraft;

1 Long final + 1 Short final => EMERGENCY for both aircraft;

[39] Procedures for simultaneous dependent operations on intersecting runways are applied at some airports, but they are not standard.

1 Short final + 1 Short final => EMERGENCY for both aircraft.

9.5.2.2.6 IR4: Final + Landing or Take off

The following cases apply only when both aircraft are converging to the runways intersection.

1 Long final + 1 Landing + converging => ABNORMAL for both aircraft;

1 Long final + 1 Take off + converging => ABNORMAL for both aircraft;

1 Short final + 1 Landing + converging => EMERGENCY for both aircraft;

1 Short final + 1 Take off + converging => EMERGENCY for both aircraft.

9.5.3 Restricted Area Incursions

The restricted area incursions only concern incursions by an aircraft into an area where the presence of an aircraft or a vehicle is forbidden permanently or temporarily. Closed TWY, ILS or MLS critical areas are example of restricted areas. When closed, runways may be considered as restricted areas. The case of incursion on a closed runway is covered separately by Surface Movement Alerting (section 2.2.2.1).

The restricted areas and their associated protections used to detect incursions should be defined locally with respect to each airport particularity. However, since restricted areas incursions deal only with ground traffic, the definition of the corresponding protection areas is easier than for runways. The protection area will be composed of only a ground boundary to detect aircraft incursions and the protection area boundary will be defined by the boundary of the restricted area (closed TWY, ILS critical area…).

An ABNORMAL will be provided to the flight crew when his aircraft enters a restricted area protection area or before the entrance if a predictive algorithm is used.

An EMERGENCY will be provided to the flight crew when his aircraft enters a restricted area or before the entrance if a predictive algorithm is used.

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