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A-SMGCS Services, Procedures, and Operational Requirements (SPOR)

"A Preliminary Concept and Framework for Validation Activities in EMMA2"

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DLR

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Table of Contents

1 Introduction

1.1 Scope of Document

The 2-D1.1.1 'A-SMGCS Services, Procedures, and Operational Requirements (SPOR)' document is one of four[1] main conceptual documents of the EMMA2 subproject 1 (SP1). The SPOR document is the central concept document within the EMMA2 project. It expresses an extensive and innovative operational concept in the field of A-SMGCS in terms of a description of:

- A-SMGCS **S**ervices (§2)
- related **P**rocedures, and (§3)
- **O**perational **R**equirements (§4).

The document has its roots in the ICAO A-SMGCS Manual [25] and the results of previous work done in predecessor projects (e.g. EMMA and EUROCONTROL A-SMGCS project). The contents of the present document will reflect the opinions, experiences, and requirements of the EMMA2 consortium that is composed of different stakeholders. ICAO states of (§1.3.14, [25]): '*There will be a continuing need for dialogue between the suppliers of services, the manufacturers, and the users so that the operational requirements can be translated into technical requirements.*' Workshops were used in EMMA2 subproject 1 (SP1) to support this approach.

The generic EMMA2 A-SMGCS concept, that defines the highest level of service descriptions, procedures, and operational requirements, has been commonly agreed among all project partners. However, the concept still admits the freedom and flexibility to derive specifications for the ground and onboard manufacturers to set up the technical system at the test sites in the EMMA2 SP2 (onboard implementations), SP3 (Prague Implementations), SP4 (Toulouse Implementations), and SP5 (Milan Malpensa Implementations), whereas the different EMMA2 test sites will mainly focus on single services of an A-SMGCS and not set up and test an complete A-SMGCS. This implies that a full validation of all new services cannot be achieved in EMMA2, particularly with the new and still less matured services like TAXI-CPDLC. Nevertheless EMMA2 will contribute a valuable amount of results and recommendations to further drive the worldwide implementation of A-SMGCS services.

The document also identifies a view on the current problems and constraints with surface operations, constraints that will be considered to outline new services and procedures and adapt them to the user needs. The assessed constraints are further used to derive hypotheses addressing operational improvements as part of sub-project 6 'Validation'.

The described concept is used to provide basic input to set up the technical test environment, traffic scenarios, the experimental design, indicators, and measurement tools in the EMMA2 sub-project 6, where specific parts of the produced SPOR concept will be validated. Particularly the new higher level services are part of this validation. Other services, like surveillance, are described in this document as well, but are already rather matured and will not be in the focus of validation.

Validation results do not feedback to this document but are compiled in the EMMA2 SP6 test reports and discussed in the analysis documents. Based on those results, the significance and consequences of the new EMMA2 A-SMGCS concept will be discussed in the recommendation report. Hence, the SPOR represents the current state of the art of A-SMGCS concept evolution and is a further milestone to a full validated, harmonised, standardised and binding A-SMGCS concept as envisaged in the SESAR Master Plan for the different capability levels.

[1] Beside the 2-D1.1.1 there are the 2-D1.1.2.a „A-SMGCS Technical Requirements – Ground Part", 2-D1.1.2.b „A-SMGCS Technical Requirements – Airborne Part", and the 2-D1.2.1 „ATM Interoperability Document".

1.2 Relationships to other A-SMGCS Concept Documents

EMMA and EMMA2 internal document sources:

The 2-D1.1.1 SPOR document aims to further develop A-SMGCS services, procedures, and operational requirements, which have already been outlined with the predecessor project EMMA by following documents mainly:

- D1.3.1u EMMA Air-Ground Operational Service and Environmental Description (OSED-update) [5],
- D1.3.5u Operational Requirements Document (ORD) [6].

The SPOR is a document of work package 1.1, whereas WP1.1 itself is composed of five working groups (WG). WG2 'Operational Concept' partners (DLR, Max Körte, AIF, AENA, ANS CR, DSNA, ENAV, DFS, and EEC) worked directly for this document, whereas WG1 'Current Constraints' (DFS, DSNA, and Max Körte), WG3 'Definition of integrated HMI' (EEC, DSNA, DFS, PAS), and WG4 'Safety Net' (PAS, EEC, DSNA, AENA, and AIF) worked indirectly for the SPOR providing excerpts of their produced working papers that were included within this document. WG5 'Technical Concept' provided two separate documents both for the ground and the airborne side (2-D1.1.2a 'A-SMGCS Technical Requirements – Ground' and 2-D1.1.2b 'A-SMGCS Technical Requirements – Airborne'). These two documents base on the 2-D1.1.1 SPOR's operational concept describing the general functional architecture and deriving technical requirements. The technical requirements in these two documents establish the basis for specific adaptations for the implementation of EMMA2 at each of the airport test sites and on-board the test aircraft.

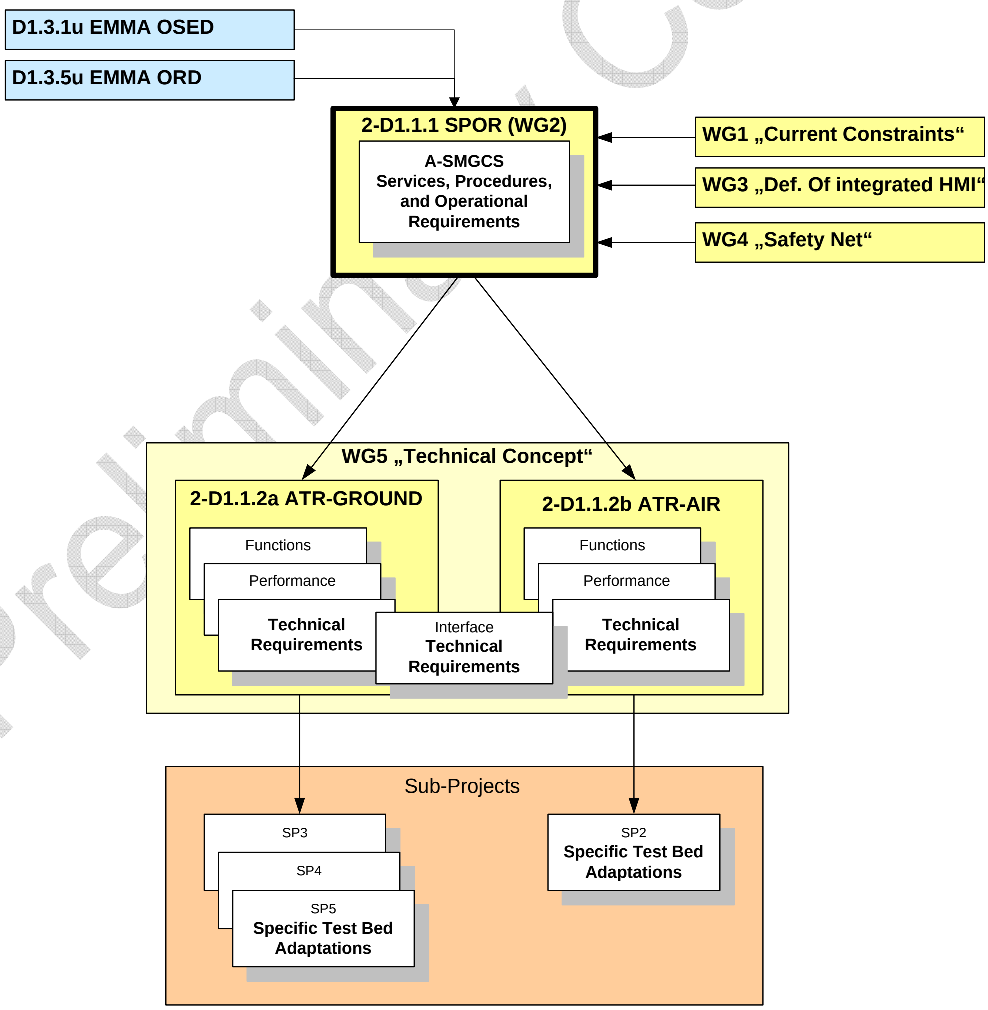


Figure 1-1: Relationship of 2-D1.1.1 SPOR document to other EMMA2 documents

External document sources:
Further external input sources are EUROCONTROL A-SMGCS documents for level I&II. The EMMA and EMMA2 operational concept bases on these EUROCONTROL concept documents when describing services and procedures for higher level A-SMGCS implementations. The following documents are of the utmost importance:

- EUROCONTROL Operational Concept & Requirements for A-SMGCS Implementation Level 1, Edition 2.0, Dec 2006, [23].
- EUROCONTROL Operational Concept & Requirements for A-SMGCS Implementation Level 2, Edition 2.0, Dec 2006, [24].
- EUROCONTROL Draft A-SMGCS Operating Procedures, Edition 1.5, Dec 2004, [17]

1.3 Acronyms

Abbreviation	Full term
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance Broadcast
AGHT	Actual Ground Handling Start Time
AGL	Above Ground Level
AIBT	Actual In-Block Time
AIP	Aeronautical Information Publication
ALDT	Actual Landing Time
AMAN	Arrival Manager
AMM	Airport Moving Map
ANSP	Air Navigation Service Provider
ANT	Airspace & Navigation Team
AOBT	Actual Off-Block Time
AOCC	Air Operations Control Centre
APDSG	ATC Procedures Development Sub-Group
APN	Apron Control
APW	Area Proximity Warning
ARDT	Actual Ready Time (for Movement)
ASAT	Actual Start- Up Approval Time
ASBT	Actual Start Boarding Time
A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ASRT	Actual Start-Up Request Time
ASTERIX	All-purpose Structured Eurocontrol Radar Information Exchanged
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATOT	Actual Take Off Time
ATS	Air Traffic Services
ATSU	Air Traffic Service Unit
ATTT	Actual Turn-round Time
AVOL	Aerodrome Visibility Operational Level
AXIT	Actual Taxi-In Time
AXOT	Actual Taxi-Out Time
BETA	operational Benefit Evaluation by Testing an A-SMGCS
CDD	Clearance Delivery Dispatcher
CDM	Collaborative Decision Making

CM	Crew Member (Flight Crew)
CPDLC	Controller Pilot Data Link Communication
CPT	Captain (Flight Crew)
CTOT	Calculated Take Off Time (CFMU)
DCDU	Data Link Control And Display Unit
DCL	Departure Clearance
DGPS	Differential Global Positioning System
DMAN	Departure Manager
DOTIS	Datalink Operations Terminal Information
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitoring
EFIS	Electronic Flight Instrument System
EFS	Electronic Flight Strips
EIBT	Estimated In-Block Time
EICAS	Electronic Indicating And Crew Alerting System
ELDT	Estimated Landing Time
EMMA	European airport Movement Management by A-SMGCS
EOBT	Estimated Off-Block Time
E-OCVM	'EUROPEAN' Operational Concept Validation Methodology
ETOT	Estimated Take Off Time
ETTT	Estimated Turn-round Time
EUROCAE	European Organisation for Civil Aviation Equipment
EXIT	Estimated Taxi-In Time
EXOT	Estimated Taxi-Out Time
FDPS	Flight Data Processing System
FMS	Flight Management System
FMS	Flight Management System
FO	First Officer (Flight Crew)
FPL	Filed Flight Plan
FPL	Filed Flight Plan
GEC	Ground Executive Controller
IFPS	Integrated Initial Flight Plan Processing System
IFR	Instrument Flight Rules
IHP	Intermediate Holding Position
ILS	Instrument Landing System
IMC	INSTRUMENT METEOROLOGICAL CONDITIONS
JAA	Joint Aviation Authority
JAR	Joint Aviation Requirements
LVP	Low Visibility Procedures
MASPS	Minimum Aircraft System Performance Specification
MCDU	Multifunctional Control and Display Unit

MET	Meteorological
MLS	Microwave Landing System
MLT	Multilateration
MSAW	Minimum Safe Altitude Warning
MTTT	Minimum Turn-round Time
NASA	National Aeronautics and Space Administration (USA)
NPA	Notice Of Proposed Amendment
OM	Operations Manual
ORD	Operational Requirements Document
OSED	Operational Services and Environment Description
PDC	Predeparture Clearance
PF	Pilot Flying
PNF	Pilot Non-Flying
POB	Persons on board
PSR	Primary Surveillance Radar
R/T	Radio telephony
RET	Rapid Exit Taxiway
RIMS	Runway Incursion Monitoring System
RPA	Reported Position Accuracy
RPL	Repetitive Flight Plan
RVR	Runway Visual Range
RWY	Runway
SARPS	Standards and Recommended Practices
SGMAN	Stand and Gate Manager
SGD	Surface Guidance Display
SGS	Surface Guidance System
SIBT	Scheduled In-Block Time
SID	Standard Instrument Departure
SIT1	CFMU Slot Issue Time
SMGCS	Surface Movement Guidance and Control Systems
SMR	Surface Movement Radar
SOBT	Scheduled Off-Block Time
SPOR	A-SMGCS Services, Procedures, and Operational Requirements
SSR	Secondary Surveillance Radar
STBY	Stand By
STCA	Short Time Conflict Alert
SWIM	System Wide Information Management
TA/RA	Traffic Advisory/Resolution Advisory
TAXI-CPDLC	TAXI – Controller Pilot Data Link Communication
TCAS	Traffic alert and Collision Avoidance System
TIS-B	Traffic Information System Broadcast

TOBT	Target Off-Block Time
TRD	Technical Requirements Document
TSAT	Target Start-up Approval Time
TSD	Traffic Situation Display
TTOT	Target Take-Off Time
TWR	Aerodrome Control Tower
TWY	Taxiway
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1.4 Explanation of terms

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

'ICAO A-SMGCS Manual' definitions 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', or from Eurocontrol documents. In that case, it is indicated in the definition.

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

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.

Aerodrome visibility operational level (AVOL) [ICAO-A-SMGCS], page (ix)

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

Airport authority [ICAO-A-SMGCS], page (ix)

The entity responsible for the operational management of the airport.

Alert [ICAO-A-SMGCS], page (ix)

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

Note: The term alert covers warnings, cautions, advisories and alarms reflecting different levels of urgency or equipment performance.

Alert Situation [EUROCAE-MASPS], page 2

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

Apron (ICAO SARPS Appendix 14) [ICAO-A-SMGCS], page (ix)
[EUROCAE-MASPS], page 2

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.

Area of interest for an A-SMGCS [ICAO-A-SMGCS]

The area of interest for an A-SMGCS is the movement area, plus a volume around the runways for aircraft on approach to each landing runway direction, at such a distance that inbound aircraft can be integrated into an A-SMGCS operation and that aerodrome movements, including aircraft departures, relevant missed approaches or aircraft crossing the relevant active runways, can be managed.

Note: Participating vehicle movements are of interest in the manoeuvring only, which is the complete area where aircraft move, except of aprons.

Participating aircraft are of interest in the approach sectors of each runway (see above) and in the complete movement area of the aerodrome (incl. apron), except of passive & empty stands.

Def. 'apron': '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.'

Def 'stand': 'A designated area on an apron intended to be used for the parking of an aircraft. Stands can be classified as:

a) active stand - a stand that is occupied by a stationary aircraft with engines operating, or on which an aircraft is moving, or that is being approached by an aircraft;

b) passive stand - a stand that is occupied by a stationary aircraft with engines not operating; or

c) empty stand - a stand that is vacant and not being approached by an aircraft.

A-SMGCS capacity [ICAO-A-SMGCS], page (ix)

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

Conflict [ICAO-A-SMGCS], page (ix)

A situation when there is a possibility of a collision between aircraft and/or vehicles

Cooperative aircraft / vehicle [EUROCAE-MASPS], page 3[2]

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

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

Data Fusion [EUROCAE-MASPS], page 3

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], page 3

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.

[2] The exact definition is for co-operative target; "target" has been replaced by "aircraft/vehicle"

Identification [ICAO-A-SMGCS], page (ix)

The correlation of a known aircraft or vehicle call sign with the displayed target of that aircraft or vehicle on the display of the surveillance system.

Identity [ICAO-4444], page 1-2

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 all aircraft/vehicles.

Incursion [ICAO-A-SMGCS], page (ix)

Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected areas 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 Procedures (LVP) [ICAO, EUR Doc 013], page (xi)

Specific procedures applied at an aerodrome for the purpose of ensuring safe operations during Category II and III approaches and/or departure operations in RVR conditions less than a value of 550m.

Manoeuvring area [ICAO-A-SMGCS], page (ix) [ICAO-Annex14]

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

Modularity [EUROCAE-MASPS], page 3

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

Movements

M. includes all movements on an aerodrome to be controlled by an ATCO: aircraft, (including helicopters), and vehicles.

Note: The term is used in accordance to ICAO doc 9830. There is no explicit definition in the document. The term 'movements' is equivalent to the term 'mobiles' used by EUROCONTROL.

Movement area [ICAO-A-SMGCS], page (ix) [ICAO-Annex14] [ICAO-4444]

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).

Note: For A-SMGCS, the movement area does not include passive stands, empty stands and those areas of the apron(s) that are exclusively designated to vehicle movements.

Non-Cooperative aircraft/vehicle [EUROCAE-MASPS], page 3[3]

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

[3] The definition is for non cooperative target, where target has been replaced by aircraft/vehicle.

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-A-SMGCS], page (ix)
[ICAO-Annex14]

All fixed (whether temporary or permanent) and aircraft/vehicle 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: Definition has been extended to all aircraft/vehicles.

Note 2: In the context of EMMA2 the following restriction is used: the A-SMGCS shall detect obstacles, 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.

Protection area

A protection area is a virtual volume around a runway, a restricted area or an aircraft/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

Reduced Aerodrome Visibility Conditions [COG/35/IP/5, Proposal of EUROCONTROL to amend the ICAO EUR Doc. 7030], A-1

Meteorological conditions such that all or part of the manoeuvring area cannot be visually monitored from the aerodrome control tower

Restricted Area

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

Route [ICAO-A-SMGCS], page (ix)

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

Runway Incursion [ICAO-A-SMGCS], page (ix)

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], page (x)

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

Surveillance [ICAO-A-SMGCS], page (x)

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

Target [ICAO-A-SMGCS], page (x)

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

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

This term was chosen to distinguish EMMA2 from CASCADE D-TAXI since small deviations exist and to distinguish from ACARS since services like D-ATIS, DCL etc. are performed by ACARS. Further on, it shall show that the concept and the messages base on the already existing CPDLC service (ICAO) as much as possible.

TAXI-CPDLC EMMA2

The term expresses 'CPDLC extensions for A-SMGCS'. This term was chosen to distinguish from CASCADE D-TAXI since small deviations exist and to distinguish services like D-ATIS, DCL etc. that are performed by ACARS but EMMA2 TAXI-CPDLC is performed by ATN. Further on, it shall show that the concept and the messages originate on the ICAO CPDLC service, which were extended to the use for ground operations.

Users of an A-SMGCS [ICAO-A-SMGCS], §3.5.19.2

There are three prime users of A-SMGCS: controllers, pilots and vehicle drivers. Each of them needs to be able to interface with the system. Additionally, the system will need to interface with other systems.

Visibility Conditions [ICAO-A-SMGCS], appendix A-2-1

Four Visibility Conditions are defined as follows in 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.

1.5 Current Constraints with Airport Surface Movements

This section provides a list of the most current constraints in regard to airport surface movement. The perspectives of the air traffic controller, the pilot, and the vehicle driver are reflected. It is not intended to explain and discuss the individual constraints. The list of current constraints is related to the E-OCVM [18] approach whereas it reflects the step 0, §0.1 'Understanding the Problem', which provides the 'ATM Problem Description'. Considering those current ATM constraints it shall enable the EMMA2 partners to tailor a much better operational concept and a much better validation design.

1.5.1 ATCOs' constraints[4]

a) Missing surveillance equipment such as surface movement radar in the control tower leads to a lack of situational awareness for the air traffic controllers especially under low visibility conditions and at night. The Taipeh (Singapore Airlines) and Linate (SAS) accidents demonstrate the possible consequences of such insufficient ATCO situation awareness.

b) The sole use of SMR equipment without complementing multilateration sensors leads to shaded (by buildings) areas and dead zones at the airfield, the ATCOs' situational awareness decreases, deviations from taxi clearances cannot be detected.

c) The lack of runway incursion automated alerting equipment puts it up to the ATCO to detect those serious conflicts by means of visual observation of the airfield and observation of surveillance equipment such as SMR. In busy working environments it will not be possible for the ATCO to permanently survey the airfield and the radar scope – failures to detect runway incursions, immediately when they occur, are programmed.

d) The complexity of runway and taxiway layouts at some international hub airports makes it extremely difficult to pre-plan a departure sequence that suits all requirements in regard to ATFM slots. ATCO workload is high, missed slots and necessary changes in departure sequence potentially reduce the airport throughput.

e) Badly designed airport layouts and capacity bottlenecks in hours of peak traffic put additional pressure on the ATCO particularly in regard to workload and stress level, which result in a decrease of situational awareness and potential incidents.

f) Computerisation of technical systems has led to an increasing number of monitors, screens and input devices such as computer keyboards and mice in the tower. Due to limited space in the working units and desks this in some cases causes ergonomic insufficiencies, sometimes those screens are mounted on top of the working consoles as far as there is already no space left inside the consoles, this in some cases even results in an obstructed outside view on parts of the runways and taxiways. An integrated HMI, designed in accordance to the needs of the tower controller, is frequently not given sufficient attention. At the same time the necessity to operate these new systems and computers leads to growing head down times for the ATCOs.

g) Air Navigation Service Providers have to manage an increased pressure on costs, which is a big challenge - increasing the levels of safety while reducing costs for equipment and personnel are aims that contradict each other. Some ANSPs in Europe have a tendency to restructure their companies in a way to make it more profitable. Consequently the number of operational personnel[5] is reduced; decisions in regard to investments and new technologies are done mainly under the aspect of costs. In many cases this leads to decisions to buy 'cheap'

[4] 16 ATCOs and 20 aerodrome control experts of 8 different Airports have contributed to this list of constraints.
[5] It is a reality that the staffing levels in some control towers are reduced to an extent that even single person operation seems to be a viable option or at least a tolerated procedure.

technical systems with reduced functionalities and characteristics that only partly suit the ATCO's needs.

h) Active air traffic controllers as the end users of the systems are often confronted with new technology only in a late stage, sometimes they see the systems for the first time when they are mounted in the tower. New technical systems are sometimes implemented when they are not reliable enough to be used in the control tower. Some functionalities do not work, false alerts appear, workarounds are necessary to operate the system. ATCO's workload is increasing, although it should be decreased and relieved from routine operations.

i) Frequency congestion result in potential read back and hear back errors.

j) Lacking English language proficiency result in potential read back and hear back errors.

k) The task complexity on the Tower is very high. ATCOs often do things in parallel by serving control frequency, doing telephone coordination, visually observing the air traffic at and in the vicinity of the airport, monitoring the radar scope, managing electronic or paper strip systems, operating lighting panels and computer systems. This multi tasking working environment is extremely complex and difficult to handle and bears the risk of mistakes and failures.

1.5.2 Pilots' constraints[6]

a) Navigational errors whilst manoeuvring the aircraft on the ground are of great concern, especially at complex and unfamiliar airports. They increase the risk of failures to comply with issued taxi clearances, which can result in deviations from assigned taxi routes or even in runway incursions.

b) At peak times of the day at the most saturated airports in Europe frequency congestion is a common reason for stand stills of the individual aircraft trying to get in contact with Ground ATCO, this is most inefficient e.g. when clearing the active runway after landing however no clearance where to taxi has been received yet.

c) Advance knowledge of taxi routes to be expected before starting taxiing to the take-off position/after landing would be of great help as well as this would expedite the traffic flow.

d) The individual aircraft on its first contact with Ground ATCO might be geographically not known, might be 'invisible' due to shadow problems.

e) Navigating in a multimillion aircraft with conventional maps and charts which have to be orientated according the aircrafts' heading manually is complicated and failure prone.

f) Insufficient airport signing and marking as well as confusing airport maps increase the workload in the cockpit, and they are often the reason for failures to comply with issued taxi clearances. They increase the potential risk of lost situational awareness and can result in a runway incursion.

g) Frequency congestion on the ground frequency at busy airports plus the problem of different levels of English language proficiency in general increase the risk of read back and hear back mistakes, the resulting deviation from the issued taxi clearance can result in head on conflicts on taxiways, runway incursions and collisions.

[6] 20 members of the "Vereinigung Cockpit" and one person from the European Cockpit Association have contributed to this list of constraints.

h) The simultaneous use of English language and local language on tower control frequencies results in a decrease of situational awareness for the pilots.

i) At international hub airports the manoeuvring area is divided in several sectors, up to four frequencies for ground control plus several frequencies for apron control and clearance delivery are not unusual (example Madrid Barajas). These results in various frequency changes for the pilots on their way from the apron to the departure runway, extremely high workload in the cockpit, situational awareness decreases.

j) Adverse weather conditions and low visibility procedures lead to a decrease in airport capacity as far as the principle of 'see and avoid' can be used only when taxiing with significantly lower taxi speeds, at the same time workload and stress level in the cockpit increase significantly.

k) Hearing mistakes when receiving ATCO clearances/instructions are quite common in spite appropriate read back procedures in place.

l) Poor airport layouts, especially the lack of perimeter taxiways lead to multiple runway crossings, these results in a significant risk of runway incursions and collisions.

m) The use of high speed exit taxiways for intersection departures decreases the cockpit view to the final approach path and the runway threshold, serious incidents and even collisions occur in result.

n) Computerised cockpits without head up displays and the need to operate these systems increase the head down times of the pilots; they decrease the situational awareness in regard to other taxiing traffic, obstacles, signs and markings.

o) The insufficient or even incorrect use of visual aids like red stop bars at different airports significantly increases the risk for runway incursions, the lack of alerting functions in the cockpit leads to a situation where pilots do not detect the infringement of the runway safety strip. On the other hand visual aids, e.g. stop-bars, are under extreme conditions, e.g. bright sunlight, hardly visible.

p) When taxiing into a stand/gate no redundant visual guidance for the Captain and the First Officer is available; most guidance system are orientated towards the Captains seat position leaving the First Officer out of the loop.

q) From the flight deck you can't look behind; for push back it would be a benefit to 'see' the traffic behind you. Several incidents are on file when an aircraft pushed back into the way of a taxiing aircraft. Aircraft, vehicles and obstacle in the vicinity of the respective aircraft impose a collision risk; flight crews are not able yet to 'see' such objects of concern.

r) NOTAMS within the AIRAC cycle of 28 days are not integrated in maps and charts available on the flight deck which is of great concern: flight crews have to memorize changes on each airport, on a daily rotation up to 6 different airports together with their individual NOTAMS have to be kept in mind which leads to omissions and mistakes.

s) If the individual flight would have knowledge whilst in flight that his/her gate/stand is still occupied after landing alternative measures could be initiated; standing on a taxiway (in the US in the 'penalty box') with running engines until the gate/stand is free is of concern economically/detrimental to the environment and must be managed more efficiently.

1.5.3 Vehicle drivers' constraints

a) Vehicle drivers operating at the manoeuvring area have to recognise the names and positions of taxiways and runways without reading airport maps; due to the relatively high speed (compared to taxiing aircraft) they have less time to see and to interpret signs and markings.

b) Runway holding positions are more difficult to recognise from the perspective of a car driver than from an aircraft cockpit.

c) Vehicle drivers very often have to drive and to determine their position on the airfield simultaneously, differently from the cockpit procedures there is no second person that can do the navigation.

d) In adverse weather conditions, under low visibility and at night it is extremely difficult for the vehicle driver to determine his/her position on the manoeuvring area and to see and avoid aircraft and fixed obstacles.

e) The vehicle driver is frequently not aware of deviations from clearances or infringements of protected areas such as runway safety strips what bears a safety risk if it is not recognised within the required time.

f) The high workload in the tower does not always allow giving sufficient traffic information to the vehicle driver, so that the vehicle driver can get information about other aircraft only based on his/her own observation.

g) The simultaneous operation of more than one radio in the car and the listening to R/T on different channels at one time leads to overlays and to failures in receiving and understanding correctly the instructions of the tower controller. Non compliance with those instructions due to a decreased situational awareness bears a safety risk.

1.5.4 Constraints with current A-SMGCS equipment

The above mentioned airport surface movement constraints in conjunction with a general lack of airport capacity at some major hub airports in Europe have led to an effect that airports in an increasing number of cases become the limiting factor for the capacity of the entire ATM system. The effects of adverse weather conditions at those airports regularly lead to capacity breakdowns and to major delays for all flights arriving or departing at those airports. In order to weaken these effects some airports (e.g. London Heathrow, Frankfurt, Prague) have started to implement basic A-SMGCS components. Even though these components already have a positive effect on safety and capacity further intense R&D efforts are necessary to improve these technologies and to extend to higher levels of A-SMGCS. The following list contains some of the reported insufficiencies of current A-SMGCS systems or system components:

a) Non compliance with transponder operating procedures by some crews leads to incomplete traffic pictures in the control tower – some targets are not displayed with label information

b) Alerting functions with regard to runway incursions do not work as reliably as required. A big number of nuisance alarms are induced especially in rain and snow conditions.

c) Moving maps and traffic displays for pilots and vehicle drivers are not available yet or they are very basic in their functionalities.

d) Airport Map Data Bases available to use on moving maps onboard aircraft or vehicles and tower controller tools still lack integrity and lack official guidelines in the perspective of a future sharing of standard airport databases consistent between all stakeholders.

e) Onboard equipment are bound to very strict certification rules, but ground tools lack an equivalent systematic qualification “stamp”.

f) Current sequencing tools for the tower controller (AMAN, DMAN, SGMAN) still do not fully exploit all efficiency aspects; they need to be combined in order to allow for a fully managed airport traffic from the gate to the take off clearance and vice versa.

g) Insufficient quality of flight data or constrained departure slots, which do not consider the constraints of other stakeholders, impose a high coordination efforts between airport stakeholders.

h) CDM considerations have to be matured to enable the global A-SMGCS concept (e.g. actual shared datalink between ATCO, Aircraft and Airline etc).

i) SWIM concept implementation should be ensured (e.g. mandatory for Airport ATCO/Aircraft datalink in approach phase to enable data sending such as “expected taxi route”)

1.6 Expected Benefits

This section does not pretend to be exhaustive in representing all potential benefits but only the most obvious ‘expected’ benefits that are directly caused by an A-SMGCS are listed. Nevertheless, also the main secondary expected are mentioned below.

A-SMGCS directly caused ‘expected benefits’:

Reduction of R/T load
Since the ATCO knows the position and identity of concerned movements provided by A-SMGCS, position reports are not necessary anymore. Further on, TAXI-CPDLC enables communication via data link that further unloads the voice channel.

Reduction of misunderstandings between ATCO and Pilot
TAXI-CPDLC, as an additional communication medium, has the advantage to exchange information electronically, displayed in an alphanumerical way or even visualised on an electronic onboard airport moving map display. This kind of communication could reduce potentially safety-critical misunderstandings between ATCO and pilot which are frequently caused by:

- A tendency to hear what is expected to hear
- Similar call signs
- Language or accent problems
- Sacrifice of standard readbacks due to time pressure

In addition to that, electronic messages can easily been stored and printed out.

Better Situation Awareness of the ATCO
The A-SMGCS traffic situation display provides the ATCO with the position and identity of all concerned movements on the surface and vicinity of the airport. Planning displays operating with electronic flight strips show the clearance status of a flight and current flight plan data. All those improved information resources will increase the ATCO’s situation awareness.

Better Situation Awareness of the Flight Crews and Vehicle Drivers
Additional graphically A-SMGCS fed onboard displays showing the own position and the surrounding traffic are additional information sources for the flight crew to navigate and steer the aircraft on the aerodrome. Particularly, in adverse sight conditions when the usual 'out of the window' information is severely impaired, a gain in the pilots' and drivers' situation awareness is expected

Reduction of average taxi time and congestions of taxi ways
A-SMGCS level 1 already fosters an average 5% reduction in the average taxi time by providing the ATCO with a complete picture of the traffic situation. New A-SMGCS services like automatic routing and planning functions, more efficient procedures, and more efficient communication will further support the ATCO to manage the taxiing traffic most efficiently. In addition to that, new onboard services like electronic moving map showing the own ship position on the aerodrome and the surrounding traffic will enable the flight crew to taxi the aircraft more efficient from the runway to the gate and vice versa. Particularly in reduced visibility conditions new A-SMGCS onboard services (e.g. head-up displays) will help to maintain the speed similar to those normally used in good visibility. This will further increase the average taxi time.

Shorter average reaction time of the ATCO to potential or even actual conflict situations
Automatic conflict predictions, detection and alerting tools (additional safety nets) monitor the current traffic situation by taking into account surveillance data and granted clearances. These data are used to crosschecks the actual and expected traffic situation and the consistency of new clearances to already granted clearances. In case of potential and actual conflicts the ATCO is alerted. Particularly in high workload situations the ATCO is supported to draw her/his attention on immediate critical situations. This will improve the average reaction time in such safety critical situations.

Shorter average reaction time of flight crews and vehicle driver to critical surface movement situations
New onboard 'surface movement alerting' services crosscheck the own ship position with current surface restrictions. In case of the aircraft is entering a restricted area (e.g. a blocked runway or a closed taxiway) or deviates from an intended track, the service warns or alerts the flight crew respectively. This will shorten the average flight crews' reaction time.

Reduction of workload to an appropriate level in demanding situations
Additional weather independent surveillance sources and the facilitated access and exchange to/of important information to the status of a flight, and more efficient communication between different ATCOs and with the flight crews and vehicle drivers will alleviate the working conditions in demanding situations for all users of an A-SMGCS.

<u>Secondary caused A-SMGCS 'expected benefits'</u>

The corporation of the above-mentioned direct A-SMGCS benefits will certainly result in secondary interaction effects like:

- Smoother coordination between the ATC control positions
- Reduced impacts on environment
- Better quality of service
- Optimised utilisation of airport resources
- Decreased airport delays and aircraft time on the ground
- More efficient flow management on airports
- Increased capacity in adverse weather conditions
- Stabilisation of safety despite increasing traffic throughput

Those *secondary* expected benefits are additionally caused by the interoperability of an A-SMGCS to its adjacent ATM systems and units (e.g. APP, AOC, or CFMU) in a CDM environment (for more details cf. EMMA2 [11]).

1.7 Alignment with SESAR

In parallel to EMMA and EMMA2 the Single European Sky legislation (SES) launched by the European Commission in March 2004 has set the political frame for actions in Europe to unlock viable growth in air transport. The "technological" part to the legislative packages of the SES was established called SESAR (Single European Sky ATM Research Programme) and is proposing a new approach to reform the ATM structure in Europe. It includes two phases, starting with the establishment of a commonly agreed European ATM Master Plan, one of the key deliverables of the SESAR Definition Phase study [40]. Building on the results of the Definition Phase (2005-2008), the Implementation Phase (2008-2013) will start covering development and deployment of the European ATM Master Plan (2008-2020).

Figure 1-2: SESAR main deliverables of the definition phase

In the meantime the SESAR definition phase has finalised its six main deliverables (D1-D6) over two years, covering all aspects of the future European ATM system, including also aspects of airport / surface management. The ATM Master Plan (D5) was published in April 2008 [40]. The EMMA 2 project was already well under way by that time and the content of the EMMA2 SPOR document was established in October 2007.

To illustrate the alignment of EMMA2 with the overall SESAR Master Plan (D5) in terms of work and time frame, the red circles identify the EMMA2 objectives supporting the master plan:

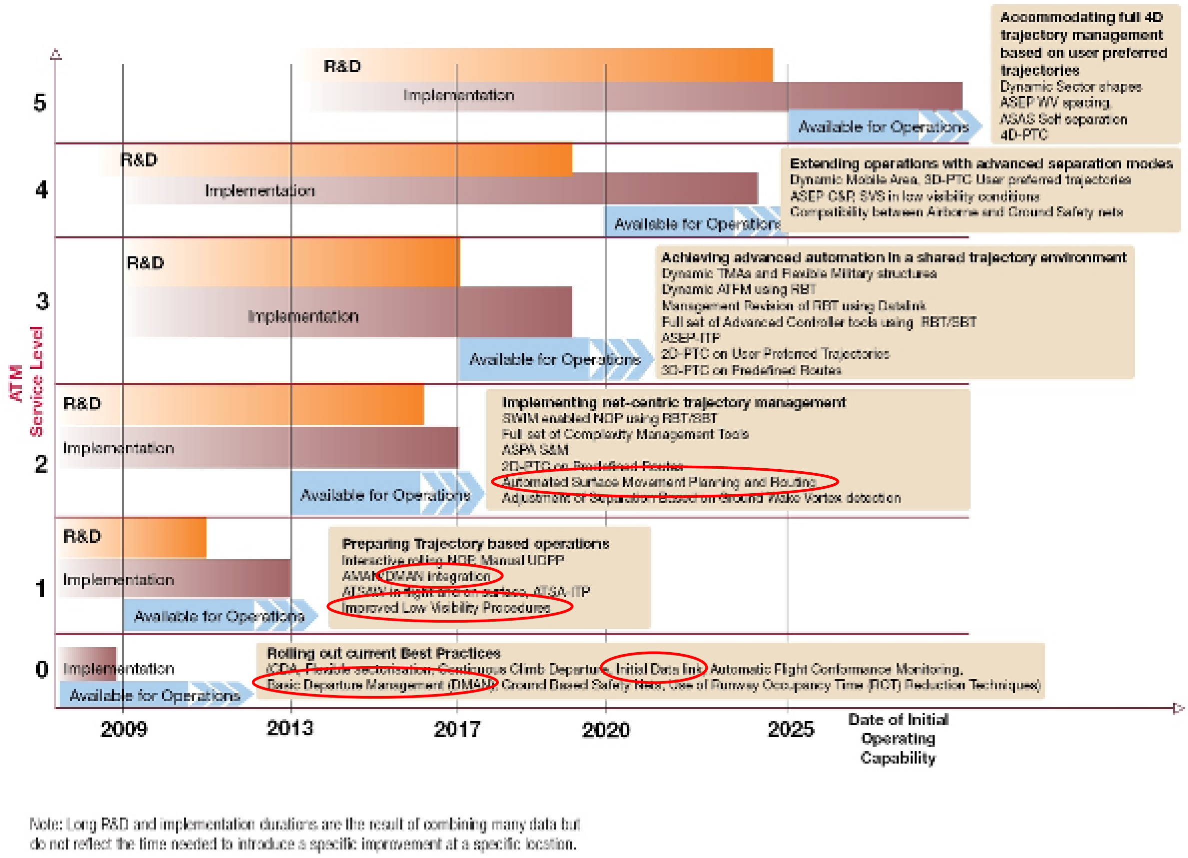


Figure 1-3: SESAR Master Plan Overview [40]

In the SESAR Gate to Gate concept the airport operations have become an integral part in which the A-SMGCS concept is identified to contribute to the SESAR programme defined in the master plan D5 [40]. The results of EMMA2 as a main A-SMGCS project have to be taken into account and this SPOR document, besides the Test Reports and Recommendation Report is to be considered as a very important contribution. Several SESAR work packages (mainly WP6 airport operations) can benefit from EMMA2 experiences:

- WP 6.6: Airport CDM
- WP 6.7 Surface Management
- WP 6.8 Runway Management
- WP 6.9 Tower Management & CWP

WP number	WP title
WP1	R&D programme management support
WP2	R&D Overall consistency
WP3	Validation Infrastructure Adaptation and Integration
WP4	En-route operation
WP5	TMA operation
WP6	Airports operation
WP7	Network operation
WP8	Information management
WP9	Aircraft System
WP10	En route/Approach ATC System
WP11	Airlines Operations Centre System
WP12	Airport System
WP13	Network System
WP14	System Wide Information Management (SWIM)
WP15	CNS System
WP16	Transversal areas

Figure 1-4: SESAR work packages

Because with WP6.7 and WP6.8 the ICAO A-SMGCS definition is split into runway and non runway operations, adequate interfaces have to be established in order to ensure a cooperation of the TWY planning service in respect to the runway occupancy.

Several other work packages of the SESAR programme are affected by A-MGCS too, e.g. from validation (WP3) up to information management (WP8) in the operational view additional the aircraft systems (WP9), airport systems (WP12) and CNS systems (WP15) in the technical view.

Further alignments of EMMA2 with SESAR will be identified in the EMMA2 document 2-D151 (Implementation Roadmap, chapter 5).

2 Service Description

This chapter identifies the various operational services that form the A-SMGCS at a 2015 time horizon taking into account the three different actors (Air Traffic Controllers [ATCOs], Flight Crews, Vehicle Drivers) who actively receive an A-SMGCS service. This description remains independent of A-SMGCS levels as defined by EUROCONTROL or EUROCAE. A-SMGCS services can hold different levels of maturity in terms of complexity and automation that look for different operational procedures. It is assumed that an A-SMGCS will be developed evolutionary by different implementation steps and that an A-SMGCS needs to be related to the operational needs of an aerodrome. An evolutionary approach has already been regarded in the EMMA OSED (§5, [5]), where a matrix for implementation steps for A-SMGCS services has been evolved (cf. §1.3.14, [25]). Descriptions in this chapter take this matrix into account in order to make a connection between the maturity of an A-SMGCS service and its applied procedures.

2.1 Services to ATC Controllers

2.1.1 Surveillance

As a first step in enhancing airport surface traffic management by A-SMGCS, improved surveillance by the introduction of an automated surveillance service shall lead to enhanced safety and efficiency of surface movement operations, with respect to visibility conditions, traffic density and aerodrome layout.

ICAO defines Surveillance as a '*function of the system which provides identification and accurate position information on aircraft, vehicles and obstacles within the designated area*' [25].

According to the ICAO A-SMGCS manual, the surveillance function is a primary function of the A-SMGCS (§2.2.1 [25]), which should '*provide accurate position information on all movements within the movement area', 'provide identification and labelling of authorized movements', 'cope with moving and static aircraft and vehicles within the coverage area of the surveillance function', 'be capable of updating data needed for the guidance and control requirements both in time and position along the route' and be unaffected by operationally significant effects such as adverse weather and topographical conditions'*(§2.5.1.1 [25]).

ICAO states that the A-SMGCS surveillance service shall '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 [25]). Moreover '*improved means of providing situational awareness to controllers, pilots and vehicle drivers*' (§1.2g) shall be in place, and 'an A-SMGCS should provide situation awareness not only to ATC but also to those aircraft and vehicles that are liable to come in proximity to each other' (§1.3.4 [25]).

In a conventional SMGCS, surveillance is performed by the controller, who has to build up a mental picture of the actual traffic situation by combining the information from different sources:

- Visual observation of the airfield,
- positioning information from Radar systems and for visually obstructed areas from video systems,
- verbal position reports from the pilots including identification,
- and flight schedule, assigned runway and stand information from the flight strips or other sources.

Building up and maintaining the necessary situation awareness is thus a complex mental process, which gets even more difficult in reduced visibility.

With the introduction of the A-SMGCS the surveillance task will remain with the ATCO, but building up the traffic picture will be automated. The A-SMGCS surveillance service shall gather and merge all relevant information automatically, discard any discrepancies between information from various sources and generate a complete and consistent image of the traffic situation.

The traffic situation information will be provided

- via the traffic situation display (TSD) to the ATCO. This allows an easier and faster perception of the situation, provides enhanced situation awareness and thereby supports the ATCO in his/her task of ground traffic surveillance and control,
- to other components of the A-SMGCS, allowing for the introduction of further A-SMGCS services which require traffic situation information, e.g. conflict and incursion prediction, detection and alerting,
- to pilots and vehicle drivers via onboard HMIs, enhancing also the onboard situation awareness.

The coverage area shall comprise the movement area but also extend to a certain altitude in order to cover missed approaches (§2.5.1.3 [25]) and the approach and departure areas in order to integrate approaching and coordinate departing traffic (§2.5.1.5 [25]).

The service must be unaffected by adverse weather conditions and applicable for (§2.4.1 [25]):

- reduced visibility conditions,
- heavy traffic density,
- complex aerodrome layout.

2.1.1.1 Sub-Functions

In order to comply with the aspects and requirements given above, the following sub-functions are necessary:

- Provision of traffic information.
- Provision of flight information for all aircraft movements.
- Data fusion to combine the information.
- Presentation of all relevant information to the ATCO via the TSD.
- Provision of surveillance information to pilots and vehicle drivers[7].

Provision of Traffic Information

The surveillance service shall continuously detect, accurately locate and identify all aircraft and vehicle movements and moreover locate obstacles in the movement area and in the vicinity of the airport. This requires:

- Non-cooperative surveillance for the detection and localisation of obstacles and non-cooperative aircraft and vehicle movements in the area of interest for an A-SMGCS.
- Cooperative surveillance for the identification, detection and localisation of equipped aircraft and vehicle movements in the area of interest for an A-SMGCS.

Non-cooperative Surveillance should be used for the locating of obstacles and non-cooperative

[7] **if required with higher level services**

movements in the movement area. In other words, the non-cooperative surveillance component shall guarantee, that every object in the movement area, either participating in the ground traffic or potentially disturbing it, can be detected. At least one non-cooperative surveillance sensor is required.

Currently Surface Movement Radar (SMR) is the standard ground surveillance sensor for SMGCS at most major airports. Depending on the installation site and the airport infrastructure, shadowing may occur in some areas, resulting in surveillance gaps. Therefore at large airports several other non-cooperative gap-fillers are installed.

Other non-cooperative sensors suitable to act as gapfillers may be e.g. microwave radars, camera systems with image processing, induction loops and magnetic sensors.

Cooperative Surveillance should be used to locate and at the same time identify correspondingly equipped aircraft and vehicles in the movement area. Since the aircraft must carry respective equipment which allows for frequent identification and location, and retrofit should be avoided, cooperative surveillance should be ideally based on equipment already available in the aircraft.

At least one cooperative sensor is required, and all participating movements should be cooperative.

Since nearly all aircraft are equipped with Mode-S transponders, an A-SMGCS should include a Mode-S Multilateration (MLAT) system nowadays, which determines the aircraft position on ground, and receives the identity and other information from onboard.

Another cooperative surveillance technology, which will come into use in the near future, is ADS-B (Automatic Dependent Surveillance - Broadcast), where the aircraft position, speed, heading, identity and other data is determined onboard and broadcasted, and received on ground and provided to the A-SMGCS surveillance service. ADS-B reports may be also received by respectively equipped aircraft and thus used to provide the traffic situation to the pilots.

Cooperative surveillance for airport ground vehicles can also be performed by MLAT or ADS-B.

Approach Surveillance should provide the information on all airborne aircraft in the vicinity of the airport, especially for the approach and departure areas of all runways, so that ground movements, including departures and the crossing of active runways, can be coordinated with traffic on approach, and that the required separations can be maintained.

The respective surveillance information can be obtained from the ASR (Airport Surveillance Radar), which is available at nearly every major airport. The ASR provides non-cooperative and cooperative surveillance information via the Radar Data Processing System (RDPS), which includes position, identification (Mode3/A code, also called squawk or SSR code) and altitude for airborne aircraft.

In the future this surveillance data could be obtained from other sensors, such as mid-range MLAT and ADS-B.

Provision of Flight Information:

Other traffic information data being relevant for the ground traffic management and the A-SMGCS services has to be gathered from diverse other ground systems at the airport, e.g. flight plan data from the FDPS (Flight Data Processing System), the correlation of the flight number with the allocated SSR code from a Code-/ Callsign data base, aircraft and vehicle type information, and stand information from the gate management system. In order to guarantee data consistency throughout the overall A-SMGCS, a central flight information processing function will process the information and store it in a database, from where it is provided to the other services.

It is vital for the proper functioning of the A-SMGCS, that all required information is reliably existing in and available from the external ground systems at the diverse stakeholders, and will be updated as soon as information has changed. Since in the conventional SMGCS some information is exchanged by human interaction only, the introduction of an A-SMGCS may require changes to external systems, which have to provide additional computerized information when linked to the A-SMGCS.

Surveillance Data Fusion:

The data fusion function is the key element of the A-SMGCS multi-sensor concept. It merges the surveillance information provided by the different surveillance sensors, providing a uniform, unambiguous image of the actual traffic situation. For each aircraft, vehicle and obstacle a track will be generated. Aircraft track data will be supplemented by flight information and aircraft data, and for vehicles respective information will be added. All track information stored will together form the traffic situation, and will be continuously and timely updated.

The traffic situation will be distributed with an update rate of at least once per second to the ATCO HMIs and to other ground and on-board services of the A-SMGCS, but also may be made available to external users in a CDM environment.

Provision of the Airport Traffic Context:

This function will provide all airport-related information, which together with the actual traffic situation forms the full picture to be presented to the ATCO. The airport traffic context includes the airport layout (runways, taxiways, apron areas, gates and building), fixed obstacles, the operational airport configuration (runway and taxiway status, restricted areas), runway thresholds, holding points, stop bars and airfield lighting and their status, further on meteorological information and time.

Some traffic context information can be gathered automatically from other systems, like airfield lighting status and weather data, but other may be entered and updated manually, like runway direction or closure.

The function therefore includes the following sub-functions:

- Acquisition of traffic context from other ground systems:
  This sub-function automatically provides information from other systems (e.g. MET systems, ATC systems, Airport systems), to which it interfaces.
- Manual input and update of traffic context:
  This sub-function provides HMI components, which allow the entry of traffic context data by human operators.

The traffic context information will be processed and combined in order to form a comprehensive traffic context image.

Human Machine Interface

This function will present the actual traffic situation together with the traffic context to the ATCO at a graphical display (TSD), which shows the airport map with superimposed symbols for all aircraft, vehicles and obstacles, and based on an at least once-a-second update the progress of the ground movements. The presentation of all information shall be concise and easy to understand, with relevant details emphasised and less relevant information reduced as applicable. At a glance the ATCO shall be able to recognise each movement and the overall traffic situation.

The TSD should show the following information:

- An accurate airport map showing the traffic context with all relevant details.
- A target symbol for each movement or obstacle, located at the map in accurate accordance to the actual position of the target in the airfield, and if required, giving information about the speed and direction of the movement.

- A label linked to each symbol for a movement, which shows the identification and other (flight) information.
- Indication of the operational status of all surveillance equipment as appropriate.

According to the concept of an integrated ATCO HMI (§2.1.5 [25]), the TSD shall also show information from other services, e.g.:

- Indication of conflicts between movements, generated by the control service
- Taxi route proposals from the routing service
- Departure time proposals from the planning service

The HMI shall be interactive and provide means to filter, input or modify information, and shall be configurable in accordance to the needs of a specific ATCO position. It shall e.g. provide means for zooming, panning, and centring the airport map. Means for choosing pre-selected areas give fast access to areas of special interest and will help to avoid that an operator loses the airport picture.

Provision of surveillance information to pilots and vehicle drivers[8]

A major issue for A-SMGCS is that ATCOs and pilots shall share the same traffic situation awareness, as they both, though with different responsibilities and competences, but in close coordination, directly contribute to the safe and efficient execution of the traffic movements.

An already mentioned means to obtain traffic information onboard is ADS-B, but with the restriction that only ADS-B equipped aircraft and vehicles can be detected by another ADS-B equipped aircraft.

In order to provide a complete traffic situation picture to the pilots, also information about non-ADS-B or non-cooperative movements and moreover obstacles has to be made available onboard. Therefore a further service, called Traffic Information Service – Broadcast (TIS-B), shall be used.

TIS-B provides the complete and consistent surveillance information, which the surveillance service has gathered on ground, via broadcast transmissions to respectively equipped aircraft and vehicles.

2.1.1.2 Technical Enablers

- Non-Cooperative surveillance system, e.g. SMR, and if required gapfillers, e.g. microwave radars, camera systems with image processing systems, induction loops and magnetic sensors
- Cooperative surveillance systems, e.g. Mode S MLAT, ADS-B based on 1090ES, VDL-4 or UAT using positional data from INS and/or GNSS
- Cooperative and non-cooperative approach surveillance by ASR, which consists of a combined PSR and SSR sensor.
- Flight Data Processing System (FDPS)
- Surveillance Data Fusion (SDF)
- Traffic Situation Display (TSD)
- Traffic Situation Service – Broadcast (TIS-B) transmitter (ground station)

2.1.1.3 Quality Aspects

The ICAO A-SMGCS Manual [25] comprises a number of performance requirements for the surveillance service:

'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 [25]).

[8] **if required with higher level services**

'*The actual position of an aircraft, vehicle or obstacle on the surface should be determined within a radius of 7.5 m*'. (§4.2.2 [25])

'*The position and identification data of aircraft and vehicles should be updated at least once per second*' (§4.2.4 [25]).

'*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 [25]).

If the identity is not updated by more than 5 seconds, the identity shown in the target label should be dropped instead of tracking it further on, in order to avoid the risk of wrong identifications by tracking malfunctions (e.g. label swapping).

In the EMMA project, a comprehensive set of performance indicators for the surveillance service of the A-SMGCS has been compiled [9], which have been validated in tests and should been taken into account when considering the quality aspects of the surveillance service.

Apart from the performance requirements, there are some other aspects which shall be highlighted. There are still A-SMGCS concepts published, which imply that surveillance may be based on non-cooperative surveillance together with acquisition of identification from approach radar and / or from identification systems placed at diverse locations in the airfield. For the areas in between, where no identification means exist, 'label tracking' shall be applied. A solution like this does not comply with the ICAO A-SMGCS concept, since ICAO requires identification with an update rate of at least 3 seconds and high probability. Concerning the performance aspects, the risk of label swapping with adjacent tracks and labels lost to nearby stationary targets like lamp posts exists.

Other concepts imply, that with the equipage of all aircraft and vehicles with cooperative onboard systems (e.g. Mode-S transponders), A-SMGCS surveillance may be based solely on cooperative means (e.g. MLAT and/or ADS-B). This will not comply with the ICAO A-SMGCS concept, since in the ICAO manual it is stated several times, that obstacles and intruders, which could be non-cooperative, shall be detected.

The use of Mode-S multilateration for cooperative surveillance requires, that appropriate transponder operating procedures are in place and that all pilots reliably comply with them. The results of the EMMA project highlight clearly the importance of this in order to guarantee the required performance of the surveillance service (§4.4, [9]). EUROCONTROL has proposed to ICAO respective transponder operating procedures [30], which should lead to a standard.

The first implementations and use of ADS-B for cooperative airport surveillance show some discrepancy between the positions given by ADS-B and the position given by other sensors (MLAT, SMR), which are considered as more accurate. The same applies also for the identification capability. Therefore it has often been decided by ANSPs not to take the ADS-B input into account in the computation of the position and identification at the SDF (Sensor Data Fusion). The following guidelines should be considered:

- It must be ensured that the technical capabilities of ADS-B are sufficient to be used in an A-SMGCS, without inducing ATCO and pilot additional workload. The performance requirements on position accuracy and probability of identification should comply with the performance of the surveillance service.
- ADS-B can be used for A-SMGCS only, when the respective standards exist, and all ADS-B equipment and the integration strictly follow the existing standards, and when the data quality is according to the requirements given by the A-SMGCS. Currently this is not guaranteed, since ADS-B is in a relatively early implementation state, and not all equipment providers and airlines seem to be aware of the situation.
- Concerning the quality of positional data and identification data different aspects apply:
    a. The accuracy of surface position data depends on the capabilities of the aircraft's navigation and avionics equipment. It must be technically ensured, that an aircraft

equipped with ADS-B carries an appropriate navigation data source. The EUROCAE document ED102, § 3.1 states examples for applications and required data sources.

b. The identification via the flight number is based on a pilot's entry during the flight preparation. It must be operationally ensured, that the pilot enters the right number for the respective flight, as performed nowadays for the transponder code (squawk).

2.1.2 Control

2.1.2.1 Service Description

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 implement the planned traffic flow and to support the tactical operations.

The control function of an A-SMGCS will ensure:

- co-ordination and transfer (locally and with adjacent airspaces);
- strategic separation through planning (DMAN, plan conformance monitoring, etc.);
- flight progress monitoring (traffic movement characterisation; interoperability with airport infrastructure, e.g. runways and gates);
- tactical separation (traffic advisories or granted clearances supported by TAXI-CPDLC, incursion and conflict prediction, detection and alerting, conflict resolution, etc.), using the surveillance service and any information retrieved through ATCOs' machine inputs

The current definition of an A-SMGCS control function (§2.5.4.1, [25]) has to be improved through the implementation and the continuous updating of tools for predicting, detecting, and resolving conflicts giving the appropriate alerts.

Furthermore, the control function should include automated support for helping the release of ATC clearances and the transfer of coordination among different ATC sectors.

Consequently, the main A-SMGCS service included in the control service are:

- Conflict prediction, detection, and alerting function
- Conflict resolution function
- Support to controller pilot communication via voice and data link
- Support for transfer of control and co-ordination within the tower and with adjacent centres

2.1.2.1.1 Conflict Prediction, Detection and Alerting

ICAO in [25] distinguishes two types of alerts short and medium term:

- *2.5.4.3 The following short-term alerts should be provided by the A-SMGCS within enough time to enable the appropriate immediate action:*
  - *a)* ***short-term conflict alert****: whereby an alert is triggered when the predicted spacing will be below preset/predefined minima;*
  - *b)* ***area penetration alert****: whereby an alert is triggered when a movement likely to enter a critical or restricted area is detected;*
  - *c)* ***deviation alert****: whereby an alert is triggered when the computed deviation will be more than the preset/predefined maximum deviation;*
  - *d)* ***runway incursion alert****: whereby an alert is triggered when a movement likely to enter an active runway (runway strip) is detected; and*
  - *e)* ***taxiway*** *(or an inactive runway being used as a taxiway) or* ***apron incursion alert****: whereby an alert is triggered when a movement likely to enter a taxiway or apron in use, which does not belong to its assigned route, is detected.*
- *2.5.4.4 Distinctive medium-term alerts should be provided well in advance to enable the appropriate remedial action to be taken with respect to:*

a) *conflict prediction;*

b) *conflict detection; and*

c) *conflict resolution.*

In relation to that description, the scope of EMMA2 conflict detection and alerting function encompasses short-term alerts and medium-term alerts, with a restriction to conflict **prediction** and **detection** (for resolution, see § 2.1.2.1.2 Conflict Resolution).

Detection of the hazardous events is required to be:

- reliable: maximizing the number of detected events while minimising the number of false alerts;
- adaptable: the control service provided by conflict detection and alerting function is to be available for all weather conditions, traffic densities and aerodrome layouts;
- preventive: the detection of hazardous events shall be performed as early as possible;
- supportive: consideration shall be put on user workload such that this new system improves the decision support capability provided to ATCOs while minimising ATCO interaction with it.

The alerting function developed in EMMA2 is actually an evolution of the concept of surface conflict alerting. This new function intends to bring forward in time the triggering of the alerts by consolidating the existing conflict detection and by performing conflict prediction.

The hypothesis used to develop the conflict prediction, detection and alerting function is the availability of an up and running surveillance function together with an interface allowing the ATCO to input clearances to the movements, for instance an e-strip HMI (see §2.4.2.2).

The EMMA2 conflict prediction, detection and alerting service does not encompass alert transmission between ground and air sides. Even though this concept seems very promising, it has been considered that it requires a system to system communication that would require a sound coordination. This kind of transmission is out of conceptual reach in the scope of EMMA2.

The EMMA2 alerting function will restrict its range of action to the manoeuvring area. The providing of alerts on apron is discarded for the following reasons:

- the distance between movements on apron is so small that it is very unlikely that any technology will allow to discriminate movements. Some trucks (baggage carts) are in physical contact with the aircraft on apron
- the time to react does not allow to provide with relevant alerts
- this area is not under ATC responsibility

With the introduction of A-SMGCS level 1&2 concept an alerting function relies on surveillance data. The augmented quality of surveillance brought by the A-SMGCS surveillance level allowed to detect movements entering the runway.

With the introduction of A-SMGCS services beyond the level 1&2 concept– and in particular with the introduction of the input of clearances via e-strip – EMMA2 alerting function proposes to perform:

- **Surveillance based alerting**: the function provided by a level 1&2 concept, whereas radar reports (SDF output) are monitored and an alert is triggered if some convergence conditions are met.
- **Conformance monitoring**: the behaviour of the movements is monitored to check if they do what they are supposed to. The conflict monitoring function permanently looks for deviations

from the instruction given by the ATCO (route conformance, clearance conformance…). Examples: deviation from assigned route, a movement entering the runway with no clearance…

- **Cross check of the clearances**: the set of clearances provided at the same time on an airport is to be cross checked in order to ensure that the set of instructions provided is consistent. Example: a crossing clearance is provided whereas a take off clearance was just provided on the same runway…

False alarms must be reduced to the minimum level in order to provide air traffic controllers with the necessary confidence in such automated support. Consequently, a step by step approach should be adopted. The system may first only detect the easiest and most dangerous alert situations and progressively be completed with other alarm situations when they are well understood.

In this regard, the implementation of the conflict prediction, detection and alerting function depends very much on the definition of the conflict cases as well as their associated operational procedures or working methods. Each airport is unique, therefore a specific tuning of the above function is required during implementation. A list (which does not claim exhaustiveness) of the main conceivable conflict cases is provided in § 3.4.

As stated by the ICAO A-SMGCS Manual §3.2.1.3 [25], the ATCO 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 ATCO.

2.1.2.1.2 Conflict Resolution

In the ICAO A-SMGCS Manual §2.5.4 [25] it is stated that in the event of conflicts, *'the A-SMGCS should be able to predict the conflict, to detect it and finally to propose a solution. 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.'*

The reliability of an automated conflict resolution depends very much on the complexity of the conflict situation and the availability of all relevant information. It is assumed that the conflict resolution function will be developed evolutionary, starting with the simplest conflicts through the more complex conflicts.

As the ATCO is responsible for the complete aerodrome traffic s/he remains the supreme authority to resolve a conflict situation. The ATCO gives instructions to pilots and vehicle driver to resolve a conflict whereas an automatic conflict resolution could support the ATCOs providing the most suitable solution. A prerequisite for a reasonable and efficiently working automatic support is that the conflict resolution function is provided with at least all traffic information the ATCO is aware of.

2.1.2.1.3 TAXI-CPDLC

With the task to apply control to the ground traffic movements, the ATCO has to issue clearances which demand from the pilot to perform an operation. Currently, ATCOs use voice communication to issue clearances, traffic information, or time information to aerodrome movements. At some airports data-link services (such as departure clearance DCL, D-ATIS) are already used to give flight crews access to important but non-time critical information. With the Link2000+ programme, EUROCONTROL has introduced a data link service for en-route control in the Maastricht UAC. For several years Oceanic Route Clearances (OORC) have been provided also via data link.

On the one hand, ICAO A-SMGCS Manual [25] gives only little advice for the use of data link in A-SMGCS. Some general principles are mentioned: '*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. Voice communications will continue to be used where necessary*' (§1.3.8 [25]), and further '*Data link may be used to supplement radiotelephony. It will be particularly useful to provide clearances and routings that are not subject to time critical transmission and that do not require instantaneous action*'

(§3.3.3.3b2 [25]).

On the other hand, ICAO provides comprehensive guidance material for the application of data link and for the respective services in the 'Manual of Air Traffic Services – Data Link Applications' [32]. The document is mainly focused on functional aspects. More operational considerations are given in the ICAO PANS-ATM document [35].

As outlined in the above mentioned documents, ICAO has defined the essential principles for:

- the communication infrastructure
- the required functionality including the set of messages to be exchanged, and
- the operational use.

It would go beyond the scope of this SPOR document to explain the details of data link, but some general aspects shall be mentioned here.

ICAO defines the communication between the ATCO and the pilot via data link (Controller Pilot Data Link Communications – CPDLC) as: '*A data link application that provides a means of communication between controller and pilot, using data link for ATC communications*.' (Explanation of terms, [32])
'
The main components of an Air Traffic service based on data link are (§1.3.5, Part I, [32]):

'*a) pilot interface;*
b) aircraft (including airborne automation);
c) air-ground and ground-ground data link communications;
d) communication interface;
e) ATC automation; and
f) controller interface.'

The following functionality is required at the ATCO HMI:

- A means to select the aircraft to which communication shall take place,
- indication whether for a specific aircraft the transmission of TAXI-CPDLC messages is possible,
- means to optionally check the course of communication,
- indication which clearance shall be transmitted,
- means for the selection of an alternative clearance or additional information, and for triggering the transmission,
- and a monitoring function which gives feedback whether the transmission was technically successful or failed, and whether a read-back confirmation from the pilot is received or not in order to close the ATC control loop.

In general, a data link services as defined by ICAO require the following functions:

- A Data Link Initialisation Capability (DLIC) provides the means to establish data link communications between the ATC ground and the aircraft systems.
- The message exchange provides the means to exchange information between the end-users.

The CPDLC main principle is described as follows:
'The CPDLC application provides the ATS facility with data link communications services. Sending a message by CPDLC consists of selecting the addressee, selecting and completing, if necessary, the appropriate message from a displayed menu or by other means which allow fast and efficient message selection, and executing the transmission. The messages defined herein include clearances, expected clearances, requests, reports and related ATC information. A 'free-text' capability is also provided to exchange information not conforming to defined formats. Receiving the message will normally take place by display and/or printing of the message.' (§6.4, Part I, [32])

The ICAO PANS-ATM document [35] explains operational aspects of the CPDLC application. Some of them, which delineate the main operational principles, shall be cited here:

'*14.1.1 The CPDLC application provides a means of communication between the controller and pilot, using data link for ATC communication.*

14.1.2 This application includes a set of clearance/information/request message elements which correspond to the phraseologies used in the radiotelephony environment.

14.1.2.1 The controller shall be provided with the capability to respond to messages, including emergencies, to issue clearances, instructions and advisories, and to request and provide information, as appropriate.

14.1.2.2 The pilot shall be provided with the capability to respond to messages, to request clearances and information, to report information, and to declare or cancel an emergency.

14.1.2.3 The pilot and the controller shall be provided with the capability to exchange messages which do not conform to defined formats (i.e. free text messages).

14.3.1.3 Except as provided by 14.3.5.1, when a controller or pilot communicates via CPDLC, the response should be via CPDLC. When a controller or pilot communicates via voice, the response should be via voice.

14.3.1.4 If a CPDLC message that requires an operational response is subsequently negotiated via voice, an appropriate CPDLC message closure response shall be sent, to ensure proper synchronization of the CPDLC dialogue.

14.3.3.1 When CPDLC is transferred, the transfer of voice communications and CPDLC shall commence concurrently.

14.3.5.4 When a CPDLC message requires a logical acknowledgment and/or an operational response, and such a response is not received, the pilot or controller, as appropriate shall be alerted.'

Up to date the implementation and use of CPDLC was focused on en-route applications. Though the ICAO documents consider the anticipated use of CPDLC also for ground control, several A-SMGCS specific aspects are still to be clarified. Some operationally significant aspects will be outlined in the following.

Data Link Performance:
In the narrow environment of the airport movement area, short reaction times are required. Retransmissions of messages due to communication failures should then be minimized. The required TAXI-CPDLC performance and especially the transfer delay will highly influence the usability and the acceptance of TAXI-CPDLC for giving clearances via data link, even when it is intended to use TAXI-CPDLC for less time-critical clearances.

ICAO (§3, Appendix A, Part I, [32]) gives the following performance requirements for en-route CPDLC:

Parameters:	Availability %	Integrity	Reliability (%)	Continuity (%)
CPDLC	99.99	10^{-7}	99.99	99.99

An important aspect is the transfer delay from the time ATC has issued a clearance until the pilot receives it. ICAO gives performance levels with corresponding delay times in seconds, which have to be applied in accordance to the operational needs of a respective application.

Performance Levels:	A	B	C	D	…	…	J
Mean end-to end transfer delay	0.5	1	2	3			60
99.996% end-to end transfer delay	0.7	1.5	2.5	5	…	…	110
99.996% end-to end	1	2.5	3.5	8			180

transfer delay							

It can be expected, that for the use of CPDLC in A-SMGCS (TAXI-CPDLC) at least performance level C will be required. This has to be seen in comparison to the available technology, which will be used in the near future.

Message Set:
The message set defined by ICAO reflects the phraseology used in verbal communication and covers mainly clearances for en-route control, apart from some messages, which are suitable also for ground use. In order to use CPDLC in A-SMGCS (TAXI-CPDLC) the existing message set has to be extended by ground clearances and ground specific information messages. A short overview shall be given here, whilst additional procedure related information follows in chapter 3.7.

Though details may differ from airport to airport, typically the course of control for an outbound flight will comprise the following clearances:

- Departure Clearance (not in the scope of EMMA2)
- De-Ice
- Start-up
- Push-back
- Taxi (together with the cleared part of the taxi route)
- Cross (active runway)
- Hold short of (holding point at an intersection or runway entry)
- Line-up or conditional line-up
- Take-off
- Handovers from CDD/APN to GEC, from GEC to TEC, and from TEC to APP.

Though details may differ from airport to airport, typically the course of control for an inbound flight will comprise the following clearances:

- Cleared to land
- Taxi (together with the cleared part of the taxi route)
- Hold short of (holding point at intersection)
- Cross (active runway)
- Handovers from TEC to GEC, and with separate APN, from GEC to APN.
- Go around (in the case a landing has to be aborted)

Before the first taxi clearance will be given, the pilot could have received information about the intended taxi route. It must be clearly differentiated between:

- Taxi route information, which comprises the complete route only for pre-informational purpose, and
- Taxi clearance, which authorizes the pilot to taxi according to the clearance along the route up to the clearance limit (first holding point).

Apart from the clearances mentioned, messages are required for the onboard side for clearance requests and acknowledgement or rejection (readback), as well as other clearances for an orderly information exchange. The EMMA2 operational design for CPDLC ground operations (TAXI-CPDLC) is outlined in chapter 3.7.

A TAXI-CPDLC message has the following characteristics:

- it consists of one or more message element(s).
- Up to 5 message elements in a single message are allowed.
- There are message elements (e.g. TAXI TO (parameter)), which can be used for a stand-alone clearance. Others can be used only as a part of a clearance (e.g. VIA TAXIWAY (parameter)) and others can be used for both (e.g. CONTACT (parameter)).

- A message element consists of one or more 'keywords', which define the type of the clearance or message, and one ore more parameters, which indicate the required information. Depending of the type of message element, parameters can be mandatory or optional.

  Example (Taxi Clearance with four message elements):
  TAXI TO STAND 241R
  VIA TAXIWAY R2 F3 E4
  WHEN REACHING TAXIWAY F3
  CONTACT GROUND NORTH 118.65

In the following an example for Prague is given, which shows the operational use of TAXI-CPDLC clearances for an inbound flight.

The aircraft has landed on RWY 24 and exited at TWY E. On the way to stand 22 it has to cross RWY 13/31 and thus to stop at the intersection.

Optionally before landing the following route information will be given by ATC:
EXPECT ROUTING TO STAND 22
VIA E F G B A

The first taxi clearance after landing would be:
TAXI TO STAND 22
VIA E F
HOLD SHORT OF RWY 13
NEXT EXPECT VIA F G B A[9]

Close to the intermediate holding point the pilot gets the voice clearance to cross runway 13/31 and to contact *Ground*.

The following taxi clearance for the rest of the route would be:
TAXI TO STAND 22
VIA F G B A

If no intermediate holding point is required, since RWY 13/31 is non-active, only one clearance with just two message elements is necessary. HOLD SHORT OF can be omitted, since the destination matches the clearance limit:
TAXI TO STAND 22
VIA E F G B A

The currently standardised ICAO CPDLC message set is intended for en-route only. However, several message elements are comprised, which can be used also for taxi applications.

The EMMA2 message element definitions for TAXI-CPDLC are based on:

- Messages from the ICAO message set defined in the documents 9694 [32] and 4444 [35], which are suitable for TAXI-CPDLC.
- The message definitions from the CASCADE D-TAXI OSED [15]. This is the main basis, as the CASCADE Operational Focus Group (OFG) has already performed a lot of work here and feedback from field trials has been considered.
- Messages from the D241_FRD_CPDLC document [8] compiled for EMMA (1) SP2. In this document Airbus (AIF) has defined a streamlined taxi message set, which was prepared with TATM, and DSNA for the first step of implementation of TAXI-CPDLC in EMMA2.

[9] The NEXT EXPECT message is written in italic because in this preliminary concept document it remains unsolved if this message element is to be sent separated from the actual cleared taxi route elements or together with the taxi clearance, which could increase the risk of confusion between expect information and clearance. In the EMMA2 validation activities both variants will be tested and results and recommendations can be found in the respective documents 2-D671 and 2-D672.

- Further message elements, which deemed to be necessary and useful in the future, were defined by EMMA2 SP1 Working Group 2.

The complete EMMA2 TAXI-CPDLC message set can be found in the respective EMMA2 test site documents for Prague, Toulouse, Malpensa, and the onboard site.

This message set is however refined during the EMMA2 validation process and the set of messages appropriate for standardization should be defined according to final results of EMMA2. For example, with the NEXT EXPECT message it remains unsolved if this message element is to be sent separated from the actual cleared taxi route elements or together with the taxi clearance, which could increase the risk of confusion between expect information and clearance. In the EMMA2 validation activities both variants will be tested and results and recommendations can be found in the respective documents 2-D671 and 2-D672 at the end of the project.

2.1.2.1.4 Sectorisation, Transfer of Control, and Co-ordination

Concerning coordination and transfer of control the ICAO PANS-ATM document [35] states the following:

the coordination and transfer of control of a flight between successive ATC units and control sectors shall be effected by a process comprising the following stages:

1. *announcement of the flight and the proposed transfer of control conditions*
2. *coordination of and agreement on the transfer of control conditions*
3. *the transfer of control to the accepting ATC unit or control sector.*

It also states that:
such agreements and instructions shall cover the following as relevant:

1. *definition of areas of responsibility and common interest, airspace structure and airspace classification(s);*
2. *any delegation of responsibility for the provision of ATS;*
3. *procedures for the exchange of flight plan and control data, including use of automated and/or verbal coordination messages;*
4. *means of communication;*
5. *requirements and procedures for approval requests;*
6. *significant points, levels or times for transfer of control;*
7. *significant points, levels or times for transfer of communication;*
8. *conditions applicable to the transfer and acceptance of control, such as specified altitudes/flight levels, specific separation minima or spacing to be established at the time of transfer, and the use of automated radar handover;*
9. *radar coordination procedures and SSR Code assignment procedures;*
10. *procedures for departing traffic;*
11. *designated holding points and procedures for arriving traffic;*
12. *applicable contingency procedures;*
13. *any other provisions or information relevant to the coordination and transfer of control of flights.*

The specific conditions for transfer of control of aircraft between the Approach sector and Tower ATCOs are predefined and published. Silent handover is the most common practice in European airports, but new methodologies are taking place such as the Automatic Transfer of Control capability (TOC) and the Automatic Assumption of Control capability (AOC).

The introduction of automation of surface movement planning and electronic flight strips support the ATCOs coordination between Ground and Tower Controllers and adjacent Approach controllers.

The definition of logical sectors in the aerodrome environment supports the Coordination and Transfer of Control procedures within this context, since it allows the identification of areas of responsibility.

Transfer of control occurs as the aircraft passes its operational phases from ‘docked to the gate’ until ‘leaving the airport’ and vice versa, in accordance to the area of responsibility for each controller position.

Transfer of control in general means transfer of responsibility, information, and communication.
In a conventional A-SMGCS the strip is handed over, and the pilot is prompted to contact the next position on the respective frequency via voice- communications.

In an A-SMGCS all services change position according to where they are needed, that means flight information (EFS), alerting, data link communications (TAXI-CPDLC) and planning go from the former to the next position, either manually triggered or automatically.
Only surveillance stays with all positions.

The transfer of control procedure can be triggered either manually or automatically, i.e. on event.
A manual TOC could be triggered by a manual quick action of the operator on the flight strip.
An automatic TOC could be triggered by any of the significant flight events listed below:

1. For departure flights:
    - Departure Clearance
    - Start-up Request
    - Start-up Clearance
    - Push-Back Clearance
    - Taxi Clearance
    - Reports on Holding Points
2. For arrival flights:
    - Taxi Clearance
    - Reports on Holding Points

A free transfer of control procedure is available to face any type of unexpected event and propose the flight to a selectable position.

Concerning Coordination and Transfer of Control between a unit providing approach control service and a unit providing aerodrome control service, the ICAO PANS-ATM document [35] states that:

1. *A unit providing approach control service shall retain control of arriving aircraft until such aircraft have been transferred to the aerodrome control tower and are in communication with the aerodrome control tower. Except when otherwise prescribed in letters of agreement or local instructions, not more than one arrival shall be transferred to a unit providing aerodrome control service during IMC.*
2. *A unit providing approach control service may authorize an aerodrome control tower to release an aircraft for take-off subject to the discretion of the aerodrome control tower with respect to arriving aircraft.*
3. *Aerodrome control towers shall, when so prescribed in letters of agreement or local instructions, obtain approval from the unit providing approach control service prior to authorizing operation of special VFR flights.*

It also states that:

1. *An aerodrome control tower shall keep the unit providing approach control service promptly advised of pertinent data on relevant controlled traffic such as:*
    a. *arrival and departure times;*

b. *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;*
c. *all available information relating to overdue or unreported aircraft;*
d. *information concerning missed approaches;*
e. *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:*
   a. *estimated time and proposed level of arriving aircraft over the aerodrome, at least fifteen minutes prior to estimated arrival;*
   b. *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;*
   c. *anticipated delay to departing traffic due to congestion.*

The handover procedure between Tower controllers and Approach controllers can be foreseen as automatically triggered: by the take off report for departing flights and by the flight distance or time to land for arriving flights.

Similarly, the Assumption of Control could be manually or automatically performed, depending on the off-line setting of the system. The setting of the system for manual or automatic AOC will depend on detailed evaluation of operational procedures and local practices.

A sectorisation plan provided for the aerodrome environment describes the link between logical functions and ATC suites, and associates each logical function to one, and only one, ATC suite. A sectorisation plan can be modified through collapsing, de-collapsing and transferring of logical functions.

The definition of a ground sectorisation, together with the ground routes for the aircraft, allows the system to automatically manage a selective distribution of flight plans among the ground positions.

The ICAO PANS-ATM document [35] states the following on 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:

1. *all aircraft for which responsibility for control will be transferred from one control position to another;*
2. *aircraft operating in such close proximity to the boundary between control sectors that control of traffic within an adjacent sector may be affected;*
3. *all aircraft for which responsibility for control has been delegated by a procedural controller to a radar controller, as well as other aircraft affected.*

Some A-SMGCS services (e.g. EFS) provide information to the 'downstream' positions, which will receive responsibility in the future, but cannot interact with the tools, since they still do not have the responsibility for a certain aircraft.

With handover to the next position, the tools for a certain aircraft will be activated at this position, and become inactive at the former.

This means that the services are or may be available at all positions, but can be actively used only at the responsible position.

The ground sectorisation configured in a Tower is based on the following types of logical sectors:

- Clearance Delivery
- Apron
- Ground
- Tower

The system should manage the following operational roles corresponding to the different ATCO (Air Traffic Control Operator) operational functions:

- Clearance Delivery
- Apron
- Ground

over the already existing operational roles foreseen for the Tower positions:

- Executive
- Planner
- Watcher

Each operational role shall be allowed to issue an off-line customisable set of orders, in order to perform its functions, so that the operator working on a Logical Console is allowed to perform all the orders that the associated operational roles have the power to issue.

It shall be possible, by means of a dedicated order issued by a supervisor role, to absorb a logical sector and to assume the operational roles of the logical console where the absorbed sector was allocated on. Conversely, it shall also be possible to release a sector that had previously been absorbed. These operations may become necessary in view of the changing traffic load on the airport. For instance during night hours it is expected that the low traffic could justify the merging of two or more sectors which would normally be separated during heavy traffic conditions during daytime.

The operators are supported in the flight management by the introduction of the electronic flight strips. Electronic flight strips operate according to the same procedures used with the paper strips, but lead to a reduced workload because to their capability to manage the flight events with quick actions on the strips.

By simple acting on the strips, they should have the capability of issuing the following orders for departing flights:

- Flight Ready
- Departure Clearance
- Push-back Clearance request
- Push-back Clearance
- Taxi Clearance request
- Taxi Clearance
- Taxi Route
- Take off Aborted
- Clearance to Take off
- Take Off Report

and the following orders for arriving flights:

- Landing Clearance

- Clearance to Land
- Landing Report
- Missed Approach
- Taxi Clearance request
- Taxi Clearance
- Taxi Route
- On-Block
- Parking Bay Assignment

The assignment of a parking bay, a taxi route and a departure/arrival runway to the flight can allow the system to identify the ground positions that will be interested by the flight, so that advance notification may be provided.

2.1.2.2 Technical Enablers[10]

- Monitoring and alerting algorithm
- Conflict resolution algorithm
- Loudspeaker
- Appropriate point to point data link application
- Integrated ATCO HMI with EFS enabling TAXI-CPDLC
- Integrated Onboard HMI enabling TAXI-CPDLC

[10] Prerequisite is an approved Surveillance Service including a Traffic Situation Display.

2.1.3 Routing / Planning

2.1.3.1 Service Description

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 routing service provided to flight crews 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 routing and
b) Transmission of a route to flight crews or to vehicle drivers, which is part of a control service and guidance service, but not routing. The taxi route is transmitted to the aircraft or vehicles either by R/T voice communication or/and by an upload data link (TAXI-CPDLC). Also flight crews' route requests via data link are part of a TAXI-CPDLC service.

Routing, as well as Surveillance, Guidance, and Control, are seen as a **primary functions** within an A-SMGCS (§2.2.1 [25]). By ICAO [25] 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 [25]).*

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 services of an A-SMGCS planning function is described within this section.

The EUROCAE 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 movements from the current position to the intended position'* [13].

By EMMA2 (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 [25].

Levels of automation of the routing function

With ICAO, the criteria whether a routing function is automated or not is the way to *assign* a route to an aircraft or vehicle (compare §2.5.2 [25]).

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

(2) When the routing function gives additional advisory information to the ATCO to assign a route, ICAO speaks of a semi-automatic routing function (§2.5.2.2 [25]).

(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 automated (§2.5.2.3 [25]).

This allocation of routing levels in terms of automation is adopted by EMMA2.

2.1.3.1.1 Manual Routing

Generally, ICAO requires that a routing function should (§2.5.2.1 [25]):

a) Be able to designate a route for each aircraft or vehicle within the movement area;
b) Allow for a change of destination at any time;

c) *Allow for a change of route;*

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

e) *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 operations).

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

- Via the A-SMGCS traffic situation 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 strips (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 any time by an authorised ATCO.

2.1.3.1.2 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 [25]). 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, de-icing procedures, etc.)

Most of this information is provided by the traditional out-the-window view, radio telephony (position reports, inspection cars), traffic situation 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 surveillance function or/and to the flight plan data processing system to get information about the:

i) Start point (Stand/Gate, runway exit)
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.

ii) End point (Final parking position, assigned runway entry point)

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

a) Local standard routes

b) Local taxi restrictions with LVO/LVP (e.g. limitations for taxiways)

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

d) Closed taxiways

e) Restricted areas

f) Obstacles

g) Temporary hazards

h) Intermediate waypoints (e.g. de-icing [at the gate/stand vs. remote de-icing stations], temporary parking positions)

i) 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 should be provided by an interface to the A-SMGCS surveillance or control function in order to avoid manual ATCO inputs.

If the ATCO object to the computed taxi route because of additional information/constraints that are not known to the routing function, the ATCO shall be able to easily select an alternative route (see also §3.5.13.8 [25]). If no suitable route proposal is available, the ATCO has to generate a route by manual means (cf. 2.1.3.1.1).

2.1.3.1.3 Automatic Routing

Automatic routing is given when the computed route is assigned by the routing function (§2.5.2.3, [25]).

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 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 [25])

When routes are assigned automatically, ICAO requires further on (§2.5.2.4 [25]):

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 [25]) defines following horizons:

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

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

iii) *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 [25]).*

'… 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 [25]).

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 Strips (EFS), sorted for out-and inbound traffic, showing all basic flight plan information the ATCO needs plus additional routing information.

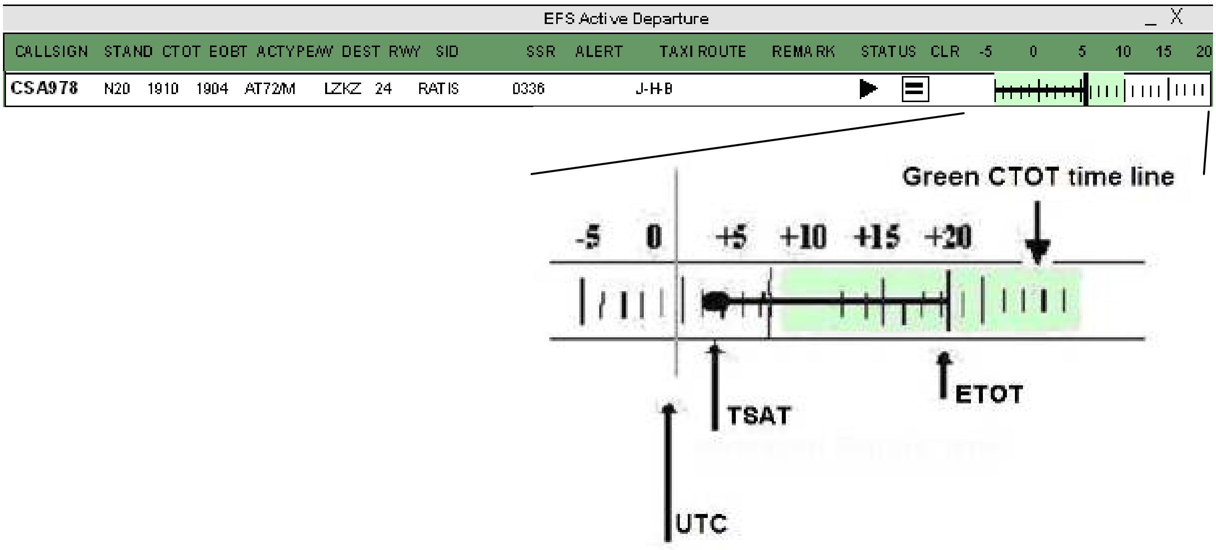
The ATCO can always intervene with this EFS display to set additional constraints unknown to the routing function. The ATCO can also cancel or change the complete route or time information. As mentioned-above, if possible, the main interaction with the routing function should be done by an assistant 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 traffic situation display (TSD) (on request of the ATCO the route could be presented graphically). Time information for outbound flights could be visualised[11] by a timeline, which contains following information:

- Estimated Take-Off time (ETOT)
- Calculated take-off time (CTOT)[12]
- Target Start-up Approval Time (TSAT)

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 ATCO:

[11] 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.
[12] If allocated to a flight.



(*source: BETA*)

Figure 2-1 - Example for Electronic Flight Strip with route and time information

The Estimated Take-Off Time (ETOT)[13] 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 ETOT, the duration of all preceding events including the time needed to start the aircraft's engine is subtracted from the ETOT to compute an efficient TSAT. 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 a TSAT:

ETOT (CTOT)[14] as the target time	[minus]
- Line-up duration	[minus]
- Taxi time	[minus]
- Push back[15] duration	[minus]
- Start-up duration[16], which depends on type of aircraft	
= Target Start-up Approval Time (TSAT)	

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

- Taxi route length, which depends on its chosen taxiway segments, which depend on
  a) Start point (parking position)
  b) End point (e.g. assigned runway, RWY entry point [intersection take-off])
  c) Local standard routes
  d) Optimisation criteria (e.g. minimise taxi time, length, or crossing conflicts)
  e) Local taxi restrictions with LVP (e.g. limitations for taxiways)
  f) Type of aircraft (some heavy aircraft may be restricted for some taxiway)

[13] Equivalent to ATC ETD–Estimated Time of Departure
[14] The ETOT are usually fixed 24 hours in advance (strategic). Updates of the ETOT, new flights plans, and CTOT allocations have to be considered by the planning function.
[15] Only with aircraft parking at gate positions
[16] Start up of engines often happens with pushback simultaneously. Has to be considered.

g) Closed taxiways, restricted areas, obstacles, temporary hazards

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

i) Heading of aircraft parking on a remote stand[17]

- Average Speed

a) Average speed per taxiway

b) Traffic density on the aerodrome[18]

c) Visibility or weather conditions[19]

d) Average speed of airliners and type of aircraft (optional)[20]

For **inbound traffic** the on-block or in-block time is computed (EIBT) taking into account the estimated landing time (ELDT) (strategic planning horizon) that is refined (pre-tactical planning) until the actual landing time (ALDT) is known (tactical planning starts). The routing function computes the taxi route and the time needed to perform this route (EXIT – Estimated Taxi-In Time). This EXIT is to be added to the ALDT to get the estimated In-block time (EIBT).

The routing function has to check if the intended final parking position (gate/stand) is available at EIBT, and if not, when it is available. The time when the final parking position is available has to be compared to the EIBT 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 calculate the needed taxi time:

- Taxi route length, which depends on its chosen taxiway segments, which depend on

a) Start point (runway exit [type of a/c, surveillance function])

b) End point (Stand/Gate)

c) Local standard routes

d) Optimisation criteria, e.g. minimise taxi time, length, or crossing conflicts

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

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

g) Closed taxiways, restricted areas, obstacles, temporary hazards

h) Intermediate waypoints (e.g. temporary parking positions when final gate/stand is occupied[21])

- Average Speed (same as for outbound)

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.

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 ETOT, ELDT, CTOT, RWY, Gate/Stand, A/C Type),

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

- The A-SMGCS surveillance and (to get position and identification, ELDT updates, ALDT)
- The A-SMGCS control function (to know about LVP, crossings and all other prevailing constraints), and
- Meteorological 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 2-1) the ATCO can easily see 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 ATCO 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, [25]).

A **validating tool** to prove the computed routes for their operational significance should be established (see §2.5.2.4f, [25]). This tool should check the route for its consistency and validity.

When a **TAXI-CPDLC service** 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[22].

2.1.3.1.4 Departure Management

With ICAO A-SMGCS Manual 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'*, [25], §2.5.4.2.

Note: 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, [25])

In EMMA2, the routing/planning service of an A-SMGCS shall be provided with a departure management (DMAN) capability or with the capability to interface with an external departure manager.

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 capability 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).

A departure management tool (known as Departure Manager [DMAN]) is a planning and decision-

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

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 more accurate target take-off time (TTOT) [16]. 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 provide an interface to an arrival management in order to take into account estimated landing times (ELDT) or even to negotiate in-and outbound traffic for optimal runway occupancy.

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

- Arrivals (ELDT, ALDT)
- CTOT/ETOT or TSAT
- Separation between aircraft depending on
  - Separation minima (based 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 Take-Off Time (TTOT)** 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, it must be aimed that a Target Start-up Approval time (TSAT) is negotiated and confirmed between ATC and the airline right in advance to meet both the airline constraints and the DMAN planning. Appropriate interfaces have to be designed to support this information exchange.

2.1.3.2 Technical Enablers

- Routing server with local routing algorithm (Surface Manager)
- Departure Manager

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 ETOT, ELDT, CTOT, RWY, Gate/Stand, A/C Type),
- The A-SMGCS surveillance (to get position and identification, ELDT updates, ALDT),
- The A-SMGCS control function (to know about LVP, crossings and all other prevailing constraints), and
- Gate Management (status of stands: passive, active, empty)

- Meteorological services (visibility)
- Airline Operator (prioritised flights, TOBT)

2.1.4 Guidance

2.1.4.1 Service Description

The ICAO A-SMGCS Manual [25]does not provide an explicit definition for the guidance function. The ICAO SMGCS Manual (Doc 9476-AN/927 – 1986 [33]) 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 [25]), 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 [25]).

Therefore, predominantly, guidance provides services for pilots and drivers, helping them to implement clearances and instructions given by the ATCO, 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:

- Visual aids for navigation
- Visual ground signals, e.g.
  - RWY, TWY and Apron markings and signs
  - RWY, TWY and Apron lighting system including controlled stop bars
- Aerodrome charts and Aircraft parking /docking charts both paper or electronic used on board
- Instructions and information from the ATCO via R/T, using light gun and pyrotechnic signals or RWY/TWY lights flashing method
- Marshalling service

Providing guidance is one of the ATCO's tasks, namely for ground executive controllers (and/or apron dispatchers if relevant), complementing their planning of ground traffic movements and their control activities in order to have the movements implemented as planned.

Guidance provided by the ATCOs 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 ATCO issues a clearance (e.g. via R/T, by switching traffic lights off or on etc.), which commands the pilot to perform an operation or to stop with the goal of preventing collision).
- Guidance is performed, when the ATCO gives instructions or traffic advisories that help to guide the aircraft or vehicle as intended or when technical means are activated, which help the pilot or vehicle driver to comply with the ATCO's intention.

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 [25]).

The guidance function shall be automated (see ICAO §1.3.2 [25]). 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 [25]).

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 [25]). 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 [25]).

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 [25]) and that these '*should be an integrated component of the system*' (§1.2 h [25]).

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 [25]).

2.1.4.1.1 Ground based Guidance

This section presents a general concept for ground based guidance. Where the respective functions are available and applicable within the EMMA2 experimental system, they should be incorporated.

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

- Selectively and/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 [25]). 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 [25]) 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 [28] 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 [28], 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 [25]).

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 ATCO 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 position to be reached, 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 [25])

In any case, whether manually or automatically operated, the ATCO must be provided with clear indications presenting the guidance provided to the pilot. ICAO §4.4 [25] 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 [25]).

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 ATCO 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 desired 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 s/he has received the respective clearance, the stop bar in front of him switches off, and the green line lightens. S/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[23].

2.1.4.1.2 Onboard based Guidance via Data Link

A further guidance means is onboard guidance, which shall be used to make guidance information automatically available or manually sent onboard the aircraft avionics. This is realised by an appropriate data link application. By itself, a 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 appropriate HMI for the ATCO is required.

ICAO states, that '*an A-SMGCS will reduce voice communications*' (§1.3.7 [25]) , 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 [25]).

[23] However, such implemented logic used during peak hours in high traffic density and complex environmental infrastructures may cause operational and technical difficulties. According to LKPR experience it is impossible to delegate such task to TEC or GEC.

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 ATCO 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 ATCO, which indicates, whether the automatic transmission of guidance information is possible for a specific aircraft, communication interface for manual data input if needed, monitoring function which gives feedback whether the transmission was technically successful or failed and read-back confirmation of clearance or information issued to close the ATC control loop.

The functionality described requires means at the ATCO HMI, which

- Allow to select the aircraft to which guidance information shall be sent,
- indicate whether for a specific aircraft the automatic transmission of guidance information is possible,
- allows to check the guidance information to be transmitted,
- allow for the selection or entry of alternative or additional guidance information, and for triggering the transmission,

and a monitoring function which gives feedback whether the transmission was technically successful or failed, and whether a read-back confirmation from the pilot is received or not in order to close the ATC control loop.

The respective HMI functionality can be accomplished e.g. via the Electronic Flight Strip display.

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

2.1.4.2 Technical Enablers

- segment-wise switchable centre line lights
- stopbars
- integrated ATCO HMI to implement ground or onboard guidance means
- data link

Dependencies with other Services or Systems

For automatic operation, the ground based visual guidance function must interact with the control service, so that an automatically planned taxi route that is granted by the ATCO 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

Dependency to appropriately designed and equipped lighting system segments as well as lighting control and monitoring system is obvious.

Quality of Service Aspects

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

- The ATCO must be provided with clear indications presenting the guidance provided to the pilot.

- ICAO §4.4 [25] 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 [25]).
- Taxiway centre line lights have to comply with the requirements and recommendations given in ICAO Annex 14, Vol.1, §5.3.15 [28]
- According to ICAO Annex 14, Vol.1, §5.3.17.13 [28], 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 ATCO must be provided with an HMI, which indicates, whether the automatic transmission of guidance information is possible for a specific aircraft, and which guidance information will be transmitted, further which provides means to select alternative or additional information and to trigger the transmission, and a monitoring function which gives feedback whether the transmission and the readback from the pilot 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 [25].

2.2 Service to Flight Crews

The automated services provided to the flight crews for surface movements in the context of an A-SMGCS are described in this section.

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

2.2.1 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 [25]).

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.

2.2.2 Surface Movement Alerting function

The main purpose of Surface Movement Alerting (SMA) function is the avoidance of runway incursions by preventing the own aircraft from entering, crossing, taking off or landing on runways without a corresponding clearance. Likewise, the crew is alerted if closed or unsuitable runways are used.

SMA has to be seen in the context of other onboard functions, since the main rationale behind the new onboard functions is not to create additional alerts on the flight deck. Rather, the intention is to enable the crew, by means of improved situational awareness, to avoid potential conflicts proactively at a strategic or pre-tactical level, and to provide alerts only for last resort conflict avoidance. Like the tactical alerts from safety net functions such as ACAS or the Terrain Awareness and Warning System (TAWS), the SMA function has to be seen as a backup or safety net function for those situations where the pure awareness functions are not sufficient to avoid a hazardous situation.

Preventive Surface Movement Alerting implies that the alerting function is armed using the same airport, operational and TAXI-CPDLC clearance data as the other onboard functions. This enables specific alerting tailored to the particular operational situation. Without operational and clearance information, it would, for example, be impossible to alert the flight crew specifically when they enter a runway that is completely closed due to heavy constructions, or when they enter or try to take off from a runway without the appropriate clearances.

2.2.3 Ground Traffic Display Function

Aircraft surface operations include the movement of aircraft and controlled 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 on an appropriate display the flight crew with the surrounding cooperative and non-cooperative surveillance traffic and its relevant information (identity, state ground/airborne) on an appropriate display;
- Provide a specific display for the conflict traffic detected by the Conflict Detection Function.

2.2.4 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 in the EMMA D1.3.1_OSED document [5].

2.2.5 Taxi-CPDLC

The TAXI-CPDLC 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 data dispatched by the ground system (taxi route clearances or expected routing information).

It is not intended to replace entirely voice communications, especially in emergency situations. 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) taxi clearance requests, responses, and possible revisions as well as expected taxi routing information. It may also cover special airport operations such as requests for de-icing.

However, some time critical controller-pilot directives such as 'CROSS RUNWAY', 'LINE-UP' or 'CLEARED FOR TAKE-OFF' may also be evaluated on some test sites as part of this service[24].

2.2.6 Braking and steering cues Function

The Braking and Steering Cues (BSC) display 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:

[24] EXPEDITE TAXI, TAXI SLOWER, and HOLD CURRENT POSITION were already invalidated by Airbus 2007 trials. Runway clearances such as CROSS, LINE-UP, TAKE-OFF, which may be considered also as time-critical, will be evaluated on Toulouse test site in 2008.

- 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.

2.2.7 HUD Surface Guidance Symbology Function

The Head-Up Navigation Subsystem is an avionic function that is designed 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 on-board applications that provide general surface situation awareness information.

The SGS/HUD function has to provide to the pilot taxiing the airplane all the necessary elements for navigation and situation awareness to ensure his/her mission keeping eyes-out. These elements must allow the pilot whatever the weather conditions may be to:

- Follow the assigned path and associated taxi clearances provided by control
- Maintain every time the airplane on the pavement
- Be able to report own-ship position to the control as requested
- Ensure the security of the airplane

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, TAXI-CPDLC function and B&SC function.

According to the various constraints due to the airplane type or to the visibility conditions, it can be consider two symbology levels:

- 1st level: Basic symbology for navigation aids useful in all visibility conditions and for all aircraft
- 2nd level: Guidance function to follow path instructions especially for low visibility conditions & big aircraft

2.2.8 Ground- Air Database Upload

The Ground-to-Air Database Upload Function is required to ensure that aircraft are always deployed and operated with up-to-date and consistent aerodrome databases. The function should cover all upload processes from initial data-loading of an airport database for the first time to short-term temporary updates while the aircraft is in flight.

In particular, the Ground-to-Air Database Upload Function should cover the following aspects:

- On-ground upload of complete aerodrome databases via data loader as part of
    - scheduled data maintenance within the AIRAC cycle
    - deployment preparation (i.e. new destination, addition to route network).

  It is expected that an avionics data loader or LAN connection (Ethernet or wireless) will be used to achieve this upload.

- On-ground database updates via data loader
- On-ground upload of information on short-term changes (NOTAM, ATIS, …). This may involve the following ways of data-loading:

- Ethernet connection to crew laptop or portable Electronic Flight Bag (EFB),
- CD-ROM,
- Compact Flash card,
- USB Stick or other non-volatile storage media
- Gatelink/WLAN

Avionics data links could be used on the ground as well, but it is not expected that they will be used due to cost-efficiency and bandwidth limitations. Avionics data loaders will most likely not be used, because that would probably necessitate the involvement of maintenance personnel before each flight.

- In-flight update of aerodrome database and short-term change information
  - Transmission via airborne avionics data link
  - Utilisation of high-bandwidth non-avionics data link

  The focus will be on short-term changes; an upload of a complete airport database will most likely be an exception.

- Manual entry of short-term changes from Pre-Flight Information Bulletin (PIB), AOCC or ATC information

2.2.9 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)
- TAXI-CPDLC ground station: to obtain the approval from the concerned ATC Controller of the departure clearance, the taxi clearance requests, the routing instruction…
- Basic alerts such as runway incursions available only with TAXI-CPDLC function (clearance recorded)
- TIS-B for uploading identity-position-state vector of non-ADS-B aircraft

2.2.10 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
- Airport mapping onboard and airport mapping at the control station consistent (same databases, as recommended by Eurocontrol safety net working group)
- 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
- Same level of reliability of data provided by ground or aircraft (certification/qualification)
- Ease of use of the TAXI-CPDLC function for taxi movements
- Efficiency of braking and steering actions in order to reduce runway occupancy time and for smooth runway vacation and taxi movements

- Streamlined and straightforward datalink exchanges (not control station or airline dedicated)
- Consistency and practical usefulness of HUD symbology

2.3 Service to Vehicle Drivers

According to ICAO doc. 9830 [25] §2 (Operational requirements), §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 [25] (Guidance on the application of the operational and performance requirements) additional vehicle driver considerations are laid down in paragraph 3.5.15:

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.

And in ICAO doc. 9830 [25] §3.5.1.6: *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

2.3.1 Airport Moving Map Function

In order to provide the services to vehicle drivers, defined in the ICAO A-SMGCS Manual (see above), 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/her vehicle on the airport surface. Especially in low visibility conditions and under complex airport layout situations it is expected that 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

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 runway incursions of vehicles, operating on the manoeuvring area
- To avoid entry to the manoeuvring area, 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) – this would require an manual input of the taxi route into the system or automatically supported by data link communication

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).

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 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. The reasons are the following:

- 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 would have to 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 manoeuvring 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.

- Own position is assessed onboard the vehicle via GPS. Position information of the surrounding traffic needs to be provided by the A-SMGCS ground surveillance via TIS-B.
- Restricted areas or closed parts of the movement area need to be displayed on the ground traffic display. These data will be obtained from the aeronautical information server / ground data base.
- Taxi route information or clearances to drive onto parts of the movement area can be given to the driver via voice communication or via data-link (TAXI-CPDLC).

2.3.7 Quality Aspects

This section identifies briefly the main aspects from the user’s perspective for the quality of service to be provided to 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. Position update rate should be high (less than 2 seconds), as far as vehicles on the movement area sometimes uses 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 by the vehicle driver with minimum 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 is due to possible high speed of the vehicles (up to 100 km/h).
- Appropriate training of vehicle drivers is essential. All vehicles drivers who are subject to drive on the movement area should receive formal training and certification – in addition to specific driving qualifications, signage and markings - related to the equipment they will operate. In particular, rules, procedures and A-SMGCS aspects in all visibility conditions which would apply to vehicle drivers should be submitted to qualification.
- Accuracy and integrity of surrounding traffic identification and positioning
- Correctness and timeliness of alarms generated by the Surface Movement Alerting and Traffic Conflict Detection functions
- Ease of use
- Avoid excessive head down time of vehicle driver

- Clear and updated information about restricted areas, obstacles and assigned route.

2.4 Integrated Human Machine Interfaces

Extract from the EMMA D6.8.1 Recommendations Report [10]:

- *HMI design aspects are important and should be given high priority*
- *Controllers and pilots are confronted with an increasing number of displays, control panels, optical and acoustical warnings and alert signals.*
- *Vehicle drivers have to operate several voice communication systems plus the new A-SMGCS displays while driving on the movement area.*
- *An optimized HMI will be a pre-condition for the handling of the new A-SMGCS functions in the cockpit, in the control tower and in special vehicles.*

The EMMA project has provided clear evidence that the evolution of A-SMGCS to more advanced services shall be accompanied with studies to improve and optimize the Human Machine Interface of new services that will be proposed to the A-SMGCS users, i.e. ATCOs, pilots and vehicle drivers.

This section is addressing the definition of HMI principles that should be considered when designing and developing HMI for new ATC system supporting EMMA2 services.

The document 'D1.3.6 Human Factors HMI Requirements' [7] delivered by the EMMA project is extended to cover the higher levels of A-SMGCS.

The HMI principles introduced in the present document are developed in closed co-ordination with the EUROCONTROL Experimental Centre and its project 'Integrated Tower Working Position' (ITWP) that is developing functional and HMI requirements for future Tower Working Positions.

Because HMIs in A-SMGCS are the link between the ATM equipment systems and users i.e. ATCOs, pilots and drivers of vehicles, the study of an 'integrated HMI' should cover both the onboard (HMI for pilot) and the ground elements (HMI for ATC controllers and vehicle drivers) of the system. Nevertheless, this section is mainly addressing the study of the HMI for ATC controllers. HMI for pilot and vehicle drivers have been studied in EMMA document D1.3.6 and has reached an acceptable level of description for EMMA2.

2.4.1 Principles for an Integrated A-SMGCS HMI

2.4.1.1 Principles description

The objective of this HMI section is not to provide a HMI solution but rather to deliver a set of HMI recommendations for an integrated HMI for future A-SMGCS, including higher-level services.

HMI principles are mostly associated to Operational Services as described in the SPOR and describe the required features needs on the ATCO position to perform the associated services.

Level of detailed description for the HMI principles should permit the development of future HMI Solutions.

Functions not addressed in EMMA2 are:

- Basic HMI elements Display and Management function (window and menu management) – To refer to EUROCONTROL ITWP

- Supporting HMI functions (Access to CWP, Management of Radar View, Access Airspace and Time information etc…) - To refer to EUROCONTROL ITWP

2.4.2 HMI Principles

2.4.2.1 Access to current traffic situation

ATCOs shall be presented with a clear 'picture' of the actual traffic situation, and with all the necessary traffic data to assist them in their control tasks.

Different sets of traffic data are to be provided in order to assist the ATCOs in different types of tasks (e.g. updating of data, planning of actions, surface conflict detection and monitoring). These sets of data shall be presented in either textual or graphical format.

- Traffic position and trajectory are provided in graphical format to help the ATCO to easily locate each aircraft or vehicle and visualise its evolution.
- Textual data can be provided in several formats:

  a) Isolated sets of data related to each aircraft or vehicle, i.e. labels. Access to the current flight parameters is provided through interaction with any aircraft or vehicle label.

  b) Lists of data allowing comparisons to help the ATCO to detect conflicts and to prioritise the planning of actions.

2.4.2.1.1 Selection of an aircraft or vehicle

The notion of selection relates to the intention to interact with the traffic label and/or with the associated symbol and trajectory, and/or its representation through traffic data. The interface should support the notion of the currently selected traffic whose data the ATCO is currently examining or modifying.

The selection of an aircraft or vehicle should:

a) Highlight all the available representations of that traffic wherever such information appears, allowing for an easy location of the traffic information.

b) Show the radar label in the appropriate selected format.

2.4.2.1.2 Display of traffic representation

The ATCO shall be provided with a clear representation of the traffic (i.e. aircraft and vehicles) to easily locate and identify aircraft and vehicles and to have a direct access to essential information.

The traffic representation shall be updated following:
a) Updates of the surveillance system
b) ATCO or system initiated update of data.

To avoid screen congestion and minimise overlap of displayed information, the permanently displayed traffic data should be only the minimum information needed by the ATCO.

The ATCO shall be provided with a clear indication that a traffic is:
a) Entering her/his area of responsibility;
b) Being under her/his responsibility;

c) Leaving her/his area of responsibility

2.4.2.1.3 Presenting data for aircraft entering or planning to enter controller area of responsibility

ATCOs shall be presented with data on all traffic entering or planning to enter a controller area of responsibility.

Traffic Data Items shall be grouped in one or several Traffic Data Lists, e.g. electronic flight strips.

Displayed Traffic Data Items displayed at each working position shall include:

a) Traffic that will become under control responsibility in the near future, and

b) Traffic under responsibility control for that position.

All Traffic Data Items pertinent to an ATCO should be presented in a clear and pre-defined format(s) that help her/him to prioritise planning and control actions. Depending on operational needs, traffic data shall be highly configurable with regard to layout, size, shape, fonts, colours and interaction capability.

Traffic under the control area responsibility of an ATCO at a particular working position should be clearly distinguished from traffic which is not under her/his control responsibility.

Traffic Data Items shall be represented in minimum format or extended format based on ATCOs' choice. It shall be possible to configure independently the extended format of Traffic Data Items from the minimum format, by displaying and removing additional data.

The ATCO shall be able to expand the format of a displayed Traffic Data Item to access additional data. By default, Traffic Data Items should be presented under normal (minimum) format.

ATCOs shall have the capabilities to sort, move, create new traffic data item in the Traffic Data Lists.

2.4.2.2 Updating current traffic situation data

ATCOs shall be presented with a mean to input clearances into the system.

Clearance input shall be made available via the electronic flight strip and/or labels.

Clearances should represent the normal set of clearance an ATCO normally gives to an aircraft such as: 'cleared to land', 'continue approach', 'go-around', 'vacate', 'cross', taxi', 'start-up', 'push-back', 'hold', 'line-up', 'conditional line-up', 'take-off', 'abort take-off' etc…

2.4.2.3 Flight Plan Edition

The ATCO should be provided with an easy and simple means to manually create a new flight plan or modify an existing flight plan.

2.4.2.4 System Supported Data Exchange and Co-ordination

The system shall support the ATCO by automatic distribution/exchange of flight data and co-ordination between control positions.

Arrival traffic data shall be displayed on control position at a time parameter before expected landing time (ELDT). The proposed time parameter should be defined at local level.

Based on local decision, Departure traffic data item shall be displayed on concerned position(s) at a time parameter before expected off block time (EOBT). The proposed time parameter should be defined at local level.

ATCOs shall be provided with system assistance for transferring aircraft control from one to another control position.

2.4.2.5 Detection and Alerting

2.4.2.5.1 Conflict Detection and Alerting

The ATCO shall be provided with clear and visible indication of a conflict alert as soon as the alert exists. The provided information should include, at the minimum the identification of the involved aircraft and/or vehicle, wherever present.

Conflict information shall be unambiguously displayed on the traffic situation display or by other appropriate means.

The use of aural signal should be restricted to highly critical events requiring immediate action. It shall always be associated with a visual signal.

An alert associated with a detected conflict should be provided with an adequate time and brought to the attention of the ATCO (**alarm coding**). An alert associated with a predicted conflict (**information coding**) should also be provided.

The information about the status of the lighting system and protection devices such as stop bars (on/off) should be easily accessible to the ATCO.

2.4.2.5.2 Plan deviation detection

The ATCO shall be provided with clear and visible indication when a movement is deviating from its cleared route. The provided information should include, at the minimum the identification of the involved aircraft, wherever present

This information should be always available to the ATCO.

The ATCO shall be provided with clear and visible indication when a movement is deviating from its clearance, or is operating without clearance e.g. an aircraft not cleared to line up enters the runway, an aircraft not cleared to land approaches…

2.4.2.6 Routing Information

The CWP shall be able to show and to assign the most probable/standard route to individual aircraft and vehicles to provide safe, expeditious, efficient and conflict-free movement from its current position to its intended position.

The ATCO shall be provided with a quick and efficient mean to modify a system assigned route to an aircraft.

2.4.2.7 Ground based information

The display of stop bars shall be integrated to the A-SMGCS HMI.

The current status of stop bars shall always be presented to the controller.

Switching (i.e. activate or de-activate) status of stop bars should be changed automatically according to ATCO clearances and a/c position.

It shall also be possible to manually switch (i.e. activate or de-activate) protection devices such as stop bars.

2.4.2.8 TAXI-CPDLC Interaction

The controller shall be informed if an aircraft is datalink equipped or not.

An alert shall be presented to the controller when a datalink dialogue has failed.

The controller shall have the means to de-activate the datalink dialogue for a particular aircraft.

2.4.2.9 Weather Information

Minimum weather information should always be displayed and available to the ATCO and should include (per runway): surface wind direction (touch down) and strength (graphical and text), QNH (mb), ATIS code, temperature and dew point.

The ATCO should be provided with an easy means to access to additional weather information that should include surface wind (Touch Down and Stop End) , visibility, current weather, cloud ceiling, QNH and QFE (mb and inches), weather forecast information, RVR conditions and a remarks section. The display should be provided either on ATCO request or automatically triggered on specific events defined at local level.

2.4.2.10 NAVAIDS Information

The ATCO should be provided with an easy means to display on request the status of airport NAVAIDS equipment.
The ATCO should be warned automatically in case of modification of airport NAVAIDS equipment serviceability.

3 A-SMGCS Procedures for Aerodrome Control Service

3.1 Regulatory Aspects

3.1.1 Air Traffic Service Provider

The current provisions governing an aerodrome control service are laid down in ICAO PANS-ATM, Doc. 4444, §7 *'Procedures for aerodrome control service'* [35]. In particular it is stated that:

'Aerodrome control towers shall ***issue information and clearances*** *to aircraft under their control…with the object of preventing collision(s)'*

and:

'Aerodrome controllers ***shall maintain a continuous watch on all flight operations*** *on and in the vicinity of an aerodrome as well as vehicles and personnel on the manoeuvring area.* ***Watch shall be maintained by visual observation****,* ***augmented*** *in low visibility conditions* ***by radar'***

In the case of surface movement radar, the nature of this augmentation is laid down in PANS-ATM chapter 8 as follows:

'The information displayed on an SMR display may be used to ***assist*** *in:*

a) Monitoring of aircraft and vehicles on the manoeuvring area for compliance with clearances and instructions;

b) Determining that a runway is clear of traffic prior to a landing or take-off;

c) Providing information on essential local traffic on or near the manoeuvring area;

d) Determining the location of aircraft and vehicles on the manoeuvring area;

e) Providing directional taxi information to aircraft when requested by the pilot or deemed necessary by the controller. Except under special circumstances, e.g. emergencies, such information should not be issued in the form of specific heading instructions;

f) Providing assistance and advice to emergency vehicles.'

In the ATS Planning Manual (ICAO Doc. 9426, Part II, §4.3.2.4, [26]) the use of SMR is summarised as follows:

'SMR can make ***a valuable contribution*** *to the safety and efficiency of aerodrome surface movement control* ***in low visibility conditions and at night****. However, it should be emphasised that* ***SMR is an adjunct and not an alternative*** *to the visual aids and procedures currently used for the control of aircraft and vehicles on the manoeuvring area.'*

Additionally, for the control of surface traffic in low visibility conditions it is stated in ICAO Doc. 4444 §7.10.1.1 [35] and Doc 9476, [33] that:

'When there is a requirement for traffic to operate on the manoeuvring area in conditions of visibility, which prevent the aerodrome control tower from applying visual separation between aircraft, and between aircraft and vehicles, the following shall apply:'

- *'At the intersection of taxiways, an aircraft or vehicle on a taxiway shall not be permitted to hold closer to the other taxiway than the holding position limit…'*

- *'The longitudinal separation on taxiways shall be as specified for each particular aerodrome by the appropriate ATS authority.*

Note: These procedures apply whenever conditions are such that all or part of the manoeuvring area cannot be visually monitored from the control tower.'

The use of words such as 'augment', 'assist' and 'adjunct' in these important documents leads to have discrepancies between different paragraphs in the same document. This leads to different interpretation by different users: e.g. 'Radar data should not be used alone in the provision of an aerodrome control service' (i.e. the term 'radar control' is not applicable to aerodrome control using SMR).

The procedures laid down in this document describe how A-SMGCS surveillance data may be used in the provision of an aerodrome control service.

3.1.2 Aircraft Operator

3.1.2.1 Basic Framework

The ICAO A-SMGCS Manual doc 9830 [25] refers to following certification and/or regulatory issues:

§3.3.2.1 '… A certification process, which is universally applied, is in place for aircraft, their operations and the avionics systems installed on board. It has agreed regulatory objectives and common procedures'.

§3.3.2 'Standardization and Certification' addresses the aircraft operator as a member of a team.

§3.3.2.4 'Certification should be a team effort. The team could comprise the A-SMGCS provider, the ATS provider, the aerodrome authority, the participating aircraft operators, and the certification authorities. Certification authorities should preferably be autonomous'.

And:

§3.3.2.2 'The meeting of the certification criteria should lead to the granting of an approval for operational use of the A-SMGCS and for participating aircraft operators.'

ICAO DOC 8168 Vol I and II [36] [37] - contrary to Doc. 4444 [35] - does not address regulatory/certification aspects in regard to the aircraft operator.

The Civil Aviation Authorities of certain European countries have agreed on detailed aviation requirements referred to as Joint Aviation Requirements (JAR) which are gradually transferred to the European Aviation Safety Agency and its regulatory documents.

JAR-OPS 1 [38] is used as a reference for regulations of commercial air transport operations. ICAO Annex 6 has been selected to provide the basic structure of JAR-OPS 1.

The requirements in JAR-OPS 1 are applicable:

> *'For operators of aeroplanes over 10 tonnes Maximum Take-Off Mass or with a maximum approved passenger seating configuration of 20 or more, or with mixed fleets of aeroplanes above and below the discriminate.'*

3.1.2.2 Specific Framework for Commercial Operators

For each operator the Operations Manual (OM) [2] describes in detail rules and regulations that have to be complied with when involved in commercial air transportation. The content of the Operations Manual must be in accordance with JAR-OPS 1 Subpart P and be approved by the respective authority.

Part A Chapter 8 of the OM which probably will have a subchapter titled 'Flight Crew Procedures in A-SMGCS environment' will describe the operators' and the flight crews' responsibility.

Certain elements of the OM are subject to specific approval by the respective authority – a list of all elements which need such approval is contained in Interpretative Explanatory Material (IEM) OPS 1.1040(b) [3]. It is anticipated that in a future update of this document A-SMGCS procedures and responsibilities will be included.

Note: Non commercial operators or operators of small aircraft who are not regulated by JAR-OPS 1 are not addressed in this document.

3.2 A-SMGCS Procedures using the Surveillance Service

3.2.1 General Use of an A-SMGCS Traffic Situation Display (TSD)

At an aerodrome, the task of the ATCO is to manage aircraft and vehicles movements in the movement area and in the vicinity of the aerodrome with respect to safety requirements and planning constraints.

The main ATCO tasks are the following:

- Identification of movements;
- Issuance of clearances and instructions to all movements;
- Monitoring the execution of the clearances;
- Monitoring traffic situation on the movement area;
- Information of pilots / drivers about traffic surrounding their aircraft / vehicle;
- Providing guidance to the movements to find their way safe and efficiently;
- Alerting the movements in case of potential or actual conflict situations.

The role of the ATCOs will not really change with the implementation of an A-SMGCS surveillance service, but the above tasks will evolve in the sense that the surveillance service will provide to the ATCO a new source of data about the traffic situation in all visibility conditions. This new source of data will complement and can also replace the usual sources to survey the traffic situation. This is done by providing the ATCO with a complete traffic situation on a designated surveillance display, also called Traffic Situation Display (TSD). The A-SMGCS traffic situation mainly includes the position and the identification of all cooperative movements and position of all non-cooperative movements (cf. also 2.1). Radio telephony (R/T) reports from co-operative movements to inform the ATCO of their position or that they have vacated the runway are not necessary anymore.

Standard A-SMGCS identification procedures

In accordance to EUROCONTROL [17] A-SMGCS surveillance identification shall be undertaken using the following actions:

- **<u>For aircraft</u>: the identification of aircraft by the ATCO is done by a direct recognition of the aircraft identification in the surveillance label of a Mode-S[25] equipped aircraft;**

[25] Or any kind of equivalent tool that provides co-operative exchanges between aircraft and the ground surveillance system (e.g.; ADS-B)

The A-SMGCS traffic situation service (TSD) will display the identity of all co-operative aircraft in a label attached to the corresponding target.

- **<u>For vehicles</u>: the identification of vehicles by the ATCO is done by a direct recognition of the vehicle identification in the surveillance label of a suitably equipped vehicle[26];**

  The A-SMGCS surveillance service will display the identity of all co-operative vehicles in a label attached to the corresponding target.

  The automatic labelling of a movement implies the use of on-board cooperative surveillance equipment that continuously provides an unambiguous identity to A-SMGCS. Since there are no ICAO transponder requirements for vehicles, they will be equipped with a suitable system, provided that a correct identification will be transmitted.

Additionally, the ATCO uses the TSD information provided by an A-SMGCS as following:

- The ATCO analyses the global traffic situation;
- The ATCO focuses on particular airport areas requiring his/her attention;
- The identification of the movements through its label allows the ATCO a more efficient identification procedure;
- The position of all the movements allows the ATCO to detect intruders, movements without authorisation;
- The movements' positions with respect to airport layout support the ATCO:
  - to set up a traffic planning,
  - to provide guidance to the pilots / drivers,
  - to anticipate and detect incursions in restricted areas and runway strips,
  - to monitor whether the movements apply the clearances s/he issued and detects deviations,
  - to inform the movements on its surrounding traffic and to anticipate collisions with other movements.

The TSD is used by the ATCO in all visibility conditions. It enables the ATCO to provide a better control service to the pilots and vehicle drivers, particularly when the ATCO's visual reference is impaired in visibility (VIS) 2, 3, and 4. Pilots are considerably affected in visibility 3 and 4. With these conditions they are not completely able to avoid each other by visual reference. The control authority is taken this into account by applying low visibility operations, which enable them to separate the traffic without the need to rely on pilots' ability to do so. A proper means to provide separation in Vis 3 or Vis 4 conditions is a blockwise control. This procedures is a very safe separation means but on the costs of efficiency. Since the A-SMGCS surveillance service provides the ATCO with a full situation awareness of the traffic situation, more efficient procedures could be used in visibility 3 and 4. Those procedures are described in §3.3.

3.2.2 Control on the Manoeuvring Area

Note: The EMMA2 definition of the <u>manoeuvring</u> area is in line with ICAO doc 9830 [25], that is, the manoeuvring area comprises 'the part of an aerodrome to be used for take-off, landing and taxiing of aircraft, excluding aprons.' In contrast, the <u>movement</u> area consists of 'the manoeuvring area <u>and</u> aprons. The area of an apron, that is outside of the legal regulations of the manoeuvring area, is not defined exactly: ICAO speaks of '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', which keeps different interpretations open. This is most likely intended because nearly every airport has its own

[26] Many systems can fit for that purpose which are or not linked with the Mode-S system. Each vehicle should have its own individual system address

> *operational agreements about the definitive borders of the apron area, its regulations, and responsibilities. However, 'for A-SMGCS, the movement area does not include empty[27] or passive[28] stands and those areas that are exclusively designated to vehicle movements'. What remains for an A-SMGCS apron, is an area that includes active stands and all areas, on which aircraft move.*

All movements entering the aerodrome manoeuvring area (runways and taxiways) must be authorised by the local ATC authority (PANS Doc 4444, §7.5.3.2.1 [35]). In order to use the TSD safe and efficiently, all movements, that intends to get authorised to use the manoeuvring area, should be properly equipped to be **co-operative** to an A-SMGCS in order to provide its identity on the TSD.

There will be a **transition phase**, when movements, which are to be authorised to enter the manoeuvring area (e.g. general aviation, vehicles that are not equipped yet) are not co-operative yet. In conditions, when visual reference is possible, the impact is rather small, but without visual reference and more than one unidentified movement at the same time, the efficient use of the TSD is impaired. Position reports have to be applied again and mental workload of the ATCO increases. In addition to that, other A-SMGCS services, which build on a reliable surveillance service are impaired, e.g. safety nets, planning and routing services.

Non-authorised movements in the manoeuvring area are intruders, which impair safety. Since the surveillance service provides at least the position of each movement at the TSD, the ATCO is supported to detect such safety critical movements, particularly in situations where the visual reference by looking out of the window is impaired. When the intruder is co-operative to the ground sensor system, the movement is identified on the TSD and the ATCO can resolve the critical situation by using its call sign and radio telephony. If the intruder is non-cooperative, the identification is not provided by the TSD and the ATCO has to apply standard operating procedures to resolve the conflict.

All other detected objects, apart from active movements, are called **obstacles**. Provided that they have an equivalent radar cross section of one square meter or more, they should be detected by the Airport surface detection equipment (ICAO doc9476, Annex F §4.2.1, [33]). To keep the manoeuvring area clear of obstacles, inspection cars are used periodically. ICAO requirements (Annex 14 [28] & Doc. 9476 [33]) will ensure that any obstacles (including those of radar cross section less than 1 square metre) and other hazards (such as surface deteriorations, standing water, failure of visual aids, lost dogs etc.) are detected. The ATCO is not responsible for detecting obstacles. The airport authority is responsible for ensuring that the manoeuvring area is 'free of obstacles'.

The following Figure 3-1 summarises the above mentioned characteristics on the manoeuvring area.

[27] A stand that is vacant and not being approached by an aircraft.
[28] A stand that is occupied by a stationary aircraft with engines not operating.

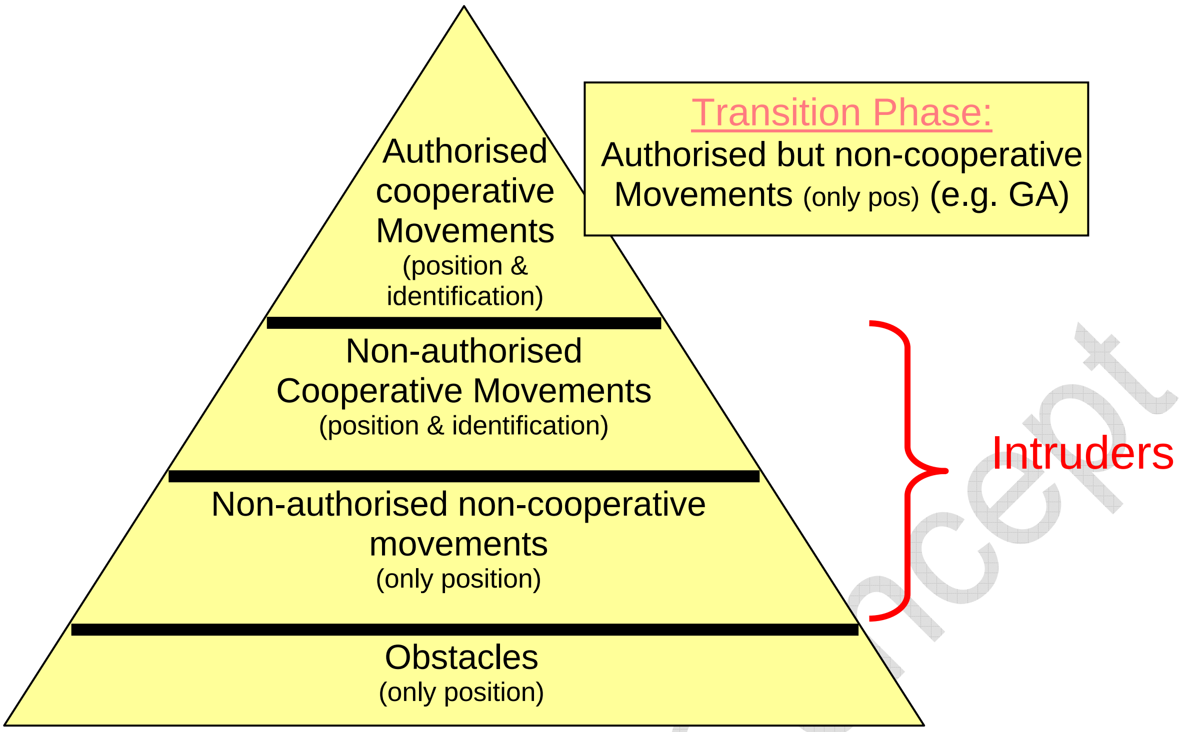


Figure 3-1: Traffic Characteristics on the Manoeuvring Area

3.2.3 Control on the Apron Area

Note: Control on an apron is either provided by the national Air Navigation Service Provider, a local apron control service that either is owned by the airport itself, or by a resident airline. Those control arrangements differ from airport to airport. For A-SMGCS it is only significant whether there is a control service or not. Hence, the document does not distinguish whether the control service is provided by an ANSP, airport, or an airline – it only speaks of 'control authority'.

For A-SMGCS, the apron area does not include empty and passive stands (only active stands) and also not those areas that are exclusively designated to vehicle movements (cf. [25]). Those areas are not under the responsibility of the control authority. Except of those excluded apron areas, the other areas, where active aircraft move, are of interest for the use of an A-SMGCS. Frequently there are coloured taxi lanes or even taxiways on an apron. Aircraft moving on those areas are to be authorised and controlled by the respective control authority. In accordance to the requirement to aircraft on the manoeuvring area (cf. §3.2.2), all controlled movements that move on the A-SMGCS apron area have to be **co-operative** that the A-SMGCS can provide their identity to the ATCO's TSD.

Beside aircraft movements, there is also a large number of vehicle movements (e.g. Follow me cars, service trucks, passenger busses, baggage trolleys, or even pedestrians), which also use taxi lanes or have to cross them occasionally. Usually, those vehicle movements are not controlled. Collisions with aircraft are avoided because they are instructed to give way to aircraft (cf. doc 4444, §7.5.3.2.2.1, [35]).

At airports, where the local apron environment allows keeping vehicle movements very limited of areas where they can collide with aircraft, local regulations could be established that vehicles must have authorisation from the control authority to use those areas. If such regulations are in force, those vehicle movements shall be co-operative to the A-SMGCS too in order to provide their identity on the ATCO's TSD automatically.

The 'see and be seen' procedure on the apron to avoid collisions between aircraft or between aircraft and vehicles is rather safe and efficient as long as the pilots and vehicle drivers can see each other. In visibility 3 and 4 this is not possible per definition, at least for pilots. The control authority applies low visibility procedures (e.g.

- vehicle movements are limited to those essential for the support of operations,
- only one aircraft is allowed to move on an apron,
- vehicles with access to areas, which are also used by aircraft have to be controlled, etc.)

to further guarantee separation between the movements. Since the ATCO uses the A-SMGCS TSD that provides him/her with a global situation awareness to survey the global traffic situation of all controlled movements, additional more efficient procedures could be applied in visibility 3 and 4. Those additional procedures are proposed in §3.3.

3.2.4 Interaction with the Traffic Situation Display (TSD)

Manual labelling

The TSD usually provides the functionality to attach a label to a non-cooperative target to track its identification that origins from sources different from an automatic A-SMGCS identification. This identity tracking would facilitate the ATCO's task, because s/he has not to re-identify it and to track it. However, a manual labelling bears also several risks:

- Assumed identification could be wrong caused by
  - an initial wrong position report
  - misunderstandings (e.g. by similar call signs or language problems)
- Call sign swapping
  - the call signs can swap to other non-cooperative movements, which pass the manual labelled movement very close
- Call sign coasting
  - the call sign is coasted to fixed objects, e.g. lamp posts on the aprons or ground guidance means on taxiways and runways

Since the ATCO relies on the label information of targets on the TSD to identify a movement, a wrong call sign bears a severe risk for a safety critical situation.

→ Therefore, manual labelling on the TSD should be avoided.

Default Setting

The TSD should provide a default setting function that is adapted to the common needs to a specific ATCO working position. Particularly during shift changes the new ATCO can easily overwrite the former settings to a known default setting.

Zooming and drag function

Beside other individual settings a very important interaction is a zooming and drag function. Preferred with the left mouse button and mouse wheel the ATCO can easily zoom into a particular area of the aerodrome surface. The default setting revokes the zooming to its standard zoom and central position.

Use of additional information on the TSD

In addition to the labelled targets on the aerodrome map, other important information can be shown to the ATCO. Which additional information is to be shown depends on local decisions and circumstances but mainly the following are of general interests:

- gate/stand numbers

- colour coding for inbound, outbound, towings, alerts, etc.
- additional flight plan information in the label:
  - aircraft type,
  - departure runway,
  - stand/gate number
  - speed
- movement history dots
- alerts and warning windows fed by a conflict monitoring function
- taxi routes on request
- stop bars' lighting operated directly via the TSD
- time (UTC)
- Wind speed and directions of the active runways
- Separate windows showing zoomed areas of the airport or the approach area

3.3 A-SMGCS Procedures using the Surveillance Service in Reduced Aerodrome Visibility Conditions

3.3.1 Foreword

Currently, the airport operations are mainly based on visual methods. Specifically, in order to manage ground movements, we have to consider that:

- the surveillance of the aerodrome is basically performed visually by the ground and tower 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';
- ATCOs, pilots, and vehicle drivers share the responsibility that operation will not create a collision hazard.

In this context, when visibility deteriorates, the major difficulties for both ATCO and flight crew come out and, as a consequence, the aerodrome performances obviously decrease. To this respect the introduction of A-SMGCS and of its advanced functionalities should represent a valid instrument to overcome this situation.

3.3.2 Introduction

In the ICAO A-SMGCS Manual (ICAO Doc. 9830, [25]), referring in particular to the sections dealing with A-SMGCS effects on aerodrome operations, the sentence '*especially in low visibility conditions*' is used very often. This is due to the fact that, since the major criticalities in airport operations arise when visibility deteriorates, the major benefits resulting from the use of A-SMGCS advanced functionalities are expected to be provided during periods of low visibility.

To this respect, this section gives an overview of A-SMGCS procedures for reduced aerodrome visibility conditions, providing guidelines and specifications for their definition.

Reduced Aerodrome Visibility Conditions are defined in the EUROCONTROL Proposal for Amendment to the ICAO SUPPs, Doc 7030 [29] as:

'Meteorological conditions such that all or part of the manoeuvring area cannot be visually monitored from the aerodrome control tower'.

During periods of reduced visibility, the ATCOs must rely on pilots' reports and surveillance sensors to monitor the spacing and prevent critical situations. So, in this case, the end-users' difficulties arise resulting then in an overall increase of workload. To this respect, the ICAO A-SMGCS Manual, §3.5.18, [25] says:

'The difficulty of navigating in low visibility conditions will place a high workload in the visual area, with a high degree of concentration required. Care should be taken that no one factor is used to the limit.'

Therefore, reduced visibility conditions represent a potentially critical situation for airport operations. In this context, the use of a full level A-SMGCS and its advanced functionalities (see §2 for more details) can be considered as a valid means to help actors involved to overcome the criticalities, and in particular to ensure the safety of airport operations. To this respect EUR Doc. 013 [31], section 7.1, states that:

'The use of Surface Movement Guidance and Control Systems (SMGCS) and Advanced Surface Movement Guidance and Control Systems (A-SMGCS) could be an enhancement to the existing surface movement provisions at the aerodrome. These systems are not a requirement to undertake operations during Low Visibility Conditions but may be provided either as a means to maintain the required capacity during operations in Low Visibility Conditions or to ensure the safety of these operations.'

Relevant European reference documents are:

- the ICAO, 'European Guidance Material on Aerodrome Operations under Limited Visibility Conditions', (EUR Doc. 013), 2nd Edition, EUR Doc. 013, April 2005 [31];
- ECAC.CEAC, 'Common European Procedures for the Authorisation of Category II and III Operations, DOC No. 17, Issue 3, 9/88 [4];
- ICAO, Procedures for Air Navigations Services - Air Traffic Management (PANS-ATM), Doc 4444, 14th Edition, 2001 [35].

3.3.3 Procedures applied during Visibility Condition 2

ICAO A-SMGCS defines [25] visibility condition 2 as:

'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'.

In visibility 2 conditions, ATC unit shall provide pilots and vehicle drivers with instructions and information to enable them to navigate and to avoid collisions with other relevant traffic by visual reference, while the spacing task remains in charge of the pilots and vehicle drivers (as it is in visibility conditions 1) [29].

In this context, the use of A-SMGCS, with special reference to levels 1 and 2 functionalities, will significantly contribute to improve the ATCOs' situational awareness and support them in providing the needed instructions and information. To this respect, using A-SMGCS, the following benefits are expected to be reached:

- no pilot position reports needed for ATCOs as they can rely on reports provided by the A-SMGCS surveillance function;

[29] It should be remarked that the overall responsibility remains in every visibility conditions with the controller who will monitor the procedure in order to ensure the compliance between aircraft movements and given instructions.

- decrease of ATCO's workload;
- improved efficiency in ground traffic management.

3.3.4 Procedures applied during Visibility Conditions 3 and 4

When visibility decreases to the lower levels, first flight crews are severely affected to avoid other traffic (visibility condition 3) and then not able to taxi on the airport surface (visibility condition 4). Specifically the ICAO A-SMGCS Manual [25] provides the following definitions:

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 an 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 an RVR of 75 m or less.'

There is no technique of ATC applied separation or spacing between taxiing aircraft which approaches the efficiency of that one applied by pilots in good visibility. It remains the interest of both ATC and pilots to leave the responsibility for collision avoidance with the pilots while conditions are such that they can safely fulfil the task. Nevertheless, when visibility reduces, the problems encountered by the pilots in maintaining safe spacing obviously increase as visual detection alone may not be adequate to ensure safe operations.

In such a context, A-SMGCS may support pilots and ATCOs in providing an efficient and safe management of aerodrome surface movement and, specifically, in providing adequate spacing between the aircraft/vehicles involved.
To this respect, the A-SMGCS ICAO Manual [25] §3.5.14.14 provides the following pilot requirements:

a) *'to be advised of the relative location of proximate aircraft, vehicles or obstructions;*
b) *to be instructed by the control authority on the action to take; and*
c) *to be provided with adequate guidance to maintain the required spacing from aircraft or vehicles in close proximity.'*

In addition the A-SMGCS Manual §3.5.14.15 states that:

'In very low visibility conditions, these actions may require additional equipment on the aircraft to manoeuvres such as:

- *to follow a preceding aircraft along a taxiway at a predetermined distance; and*
- *to pass by another aircraft or vehicle at close range.'*

Specifically, the needed additional equipment can be represented by the advanced on-board A-SMGCS technologies, such as airport moving map function, ground traffic display function, etc. (see §2.2 for more details), aiming at significantly improving the flight crews' situational and positional awareness.

At this stage, using A-SMGCS, different objectives may be reached according to the level of the implementation of the on-ground and on-board systems.

These objectives can be summarised as in the following:

- efficiency increase for ground traffic movements (a/c + vehicles);
- capacity increase while maintaining or increasing the required safety level;
- ATCO’s situational awareness increases;
- Pilot’s situational awareness increases;

3.3.4.1 Visibility Condition 3

This subsection provides the different possible spacing methods that could be applied in visibility condition 3 according to the level of A-SMGCS functionalities implemented on airborne and ground segments.

3.3.4.1.1 Today: Block Spacing Control

Preconditions:

- Surface markings (e.g. stop bars), which set the boundaries of the blocks and which have to be identifiable by the pilots in VIS3 conditions,

Method Description:
Currently, according to what stated in the SMGCS Manual, section 4.5.10 [33], the block spacing control is applied in visibility condition 3 (VIS3) for ensuring adequate spacing between two succeeding aircraft. The method foresees that the 1st block has to be left by the 1st aircraft, before the 2nd aircraft enters it. According to the ICAO definition [25], in VIS3 pilots are not able to avoid collision and then the responsibility of providing adequate spacing is assumed by the Aerodrome Control Tower (TWR), differently, thus, from visibility conditions 1 and 2, where this task is in charge of the pilot.

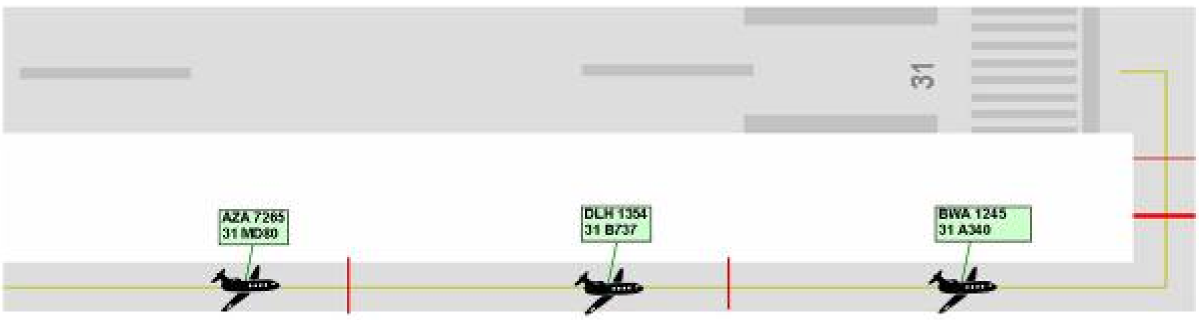


Figure 3-2: Today: Block Spacing Control.

Note: the block-based spacing can be applied without SMR or A-SMGCS, basing on pilot’s position reports.

3.3.4.1.2 ‘Tomorrow’: Enhanced Block Spacing Control

Preconditions:

- Surface markings (e.g. stop bars), which set the boundaries of the blocks and which have to be identifiable by the pilots in VIS3 conditions,

- Ground implemented A-SMGCS functionalities: surveillance and conflict prediction, detection, and alerting.

Method Description:
The block spacing methodology described in the previous section is still applied for ensuring adequate spacing. In this context, the availability of A-SMGCS enhanced surveillance and control functionalities on the ground segment could allow reducing the size of the blocks and then to improve the taxiway throughput.

On the other hand, it should be noted that:

- reducing the block size implies:
    1. additional ground infrastructures (e.g. stopbars, etc.) as visual references are needed for the pilots to hold at the end of a block;
    2. an increase of the stop and go;
- the 'block spacing method' generates such a high level of ATCO workload and frequency congestion that its use is suggested only with a very low traffic level (SMGCS Manual, section 4.5.11). To this respect, the use of A-SMGCS additional functionalities should contribute to overcome these limitations (e.g. TAXI-CPDLC support will reduce frequency congestion).

3.3.4.1.3 The 'day after tomorrow': Virtual Block Spacing Control

Preconditions:

- On-board implemented A-SMGCS functionalities: Moving Map.
- Ground implemented A-SMGCS functionalities:
    - surveillance;
    - conflict prediction, detection, and alerting[30];
    - routing.

Method Description:
It refers to the same concept as already described for enhanced block spacing control (see above). The difference in this case is that the reduction of block sizes can be performed by introducing virtual blocks and virtual stop bars on the ATCO's Traffic Situation Display (TSD), which correspond to stop bars on the pilot's moving map display. The moving map function[31] is required to provide the pilot with the needed positional awareness in order to allow her/him stopping in accordance to the virtual stop bar. The route conformance check will alert ATCO in case of 'virtual' and real stop bar infringement. Therefore, in this context, the TWR remains responsible for providing the appropriate spacing.

[30] Including route conformance monitoring.
[31] The use of moving-map display requires that always the current airport map data base is used that complies with the actual airport configuration.

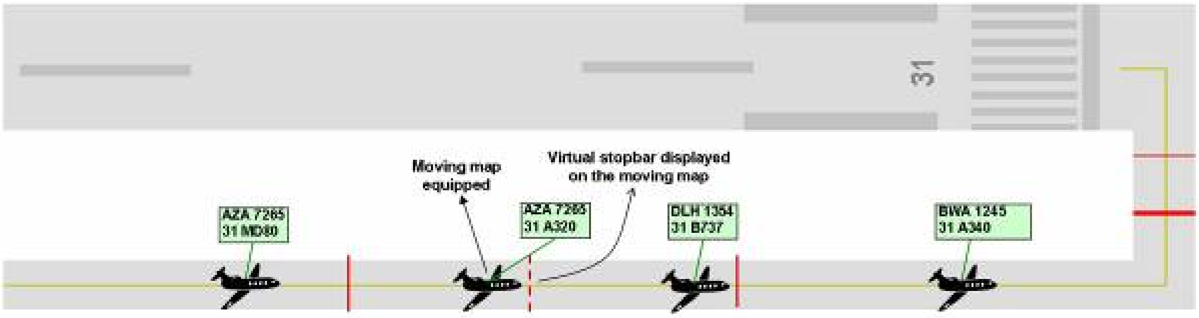


Figure 3-3: The day after tomorrow: Virtual Block Spacing Control.

3.3.4.1.4 'Next week': Safety Bubble Spacing Control

Preconditions:

- On-board implemented A-SMGCS functionalities:
  - moving map,
  - ground traffic display.
- Ground implemented A-SMGCS functionalities:
  - surveillance;
  - conflict prediction, detection, and alerting[32];
  - routing.

Method Description:

As previously outlined, the block spacing control moves the responsibility for spacing from pilot to TWR. To this respect, the way to overcome the block spacing control and its limitations (e.g. one aircraft within each block, ATCO workload, the need of ground infrastructures, continuous stop and go, etc.) should rely on the implementation of on-board equipments able to significantly improve the pilots traffic situation awareness by providing them a complete traffic picture, which would enable them to avoid collision with other traffic.

To this respect, advanced on-board A-SMGCS technologies represent valid enablers to reach the needed improvement. Specifically, the required functionalities are represented by moving map and ground traffic display (see §2.2 for more details), technically enabled by an onboard traffic display, ADS-B in/out and TIS-B. A so-equipped aircraft should allow pilot being able to follow a preceding aircraft at a predetermined distance basing on the information provided by the on-board traffic display. In addition to that, from the ground side, an advanced control function (ground safety net) should be provided to the ATCOs in order to alarm them well in advanced in case of possible critical situations ensuring thus the safety of the operations.

In this context, the 'safety bubble' spacing concept can be applied. This concept relies on the introduction of safety bubbles around each aircraft, whose size depends on aircraft and aerodrome related parameters (e.g. RVR, speed, type, wingspan, etc.). The so-obtained safety net provides ATCOs with warnings and alarms in case of bubble intersections.

Within this framework, the ATCO should be able to manage the traffic issuing instruction like the following:

[32] Including route conformance monitoring.

'AZA 7265 taxi to holding point RWY31 via TWY Tango, follow preceding traffic DLH 1354 Boeing 737 at XXX metres'.

Therefore, applying the bubble spacing control, the task for the appropriate spacing with surrounding traffic can be shared between ATCO and pilots. The sharing of the spacing task between ATCO and flight crew aims at reducing the number of actions for the ATCO and thus at decreasing his/her workload.

This should result in a valuable improvement of the efficiency and capacity management of the ground movements (e.g. more than one aircraft within the same block), while maintaining the needed safety level.

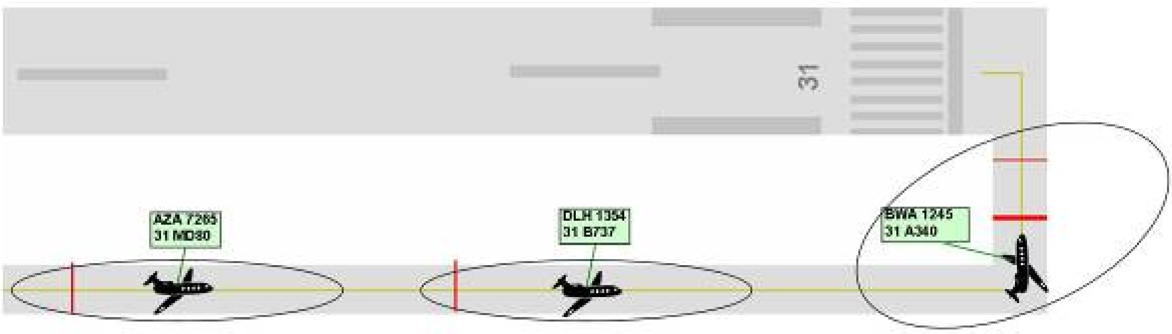


Figure 3-4: 'Next week': Safety Bubble Spacing Control.

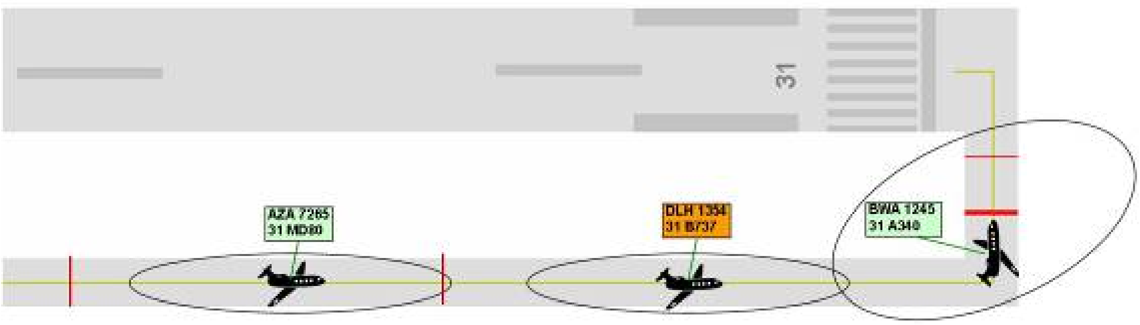


Figure 3-5: Safety Bubble Spacing Control – Stage 1 INFORMATION Alert provided to ATCO.

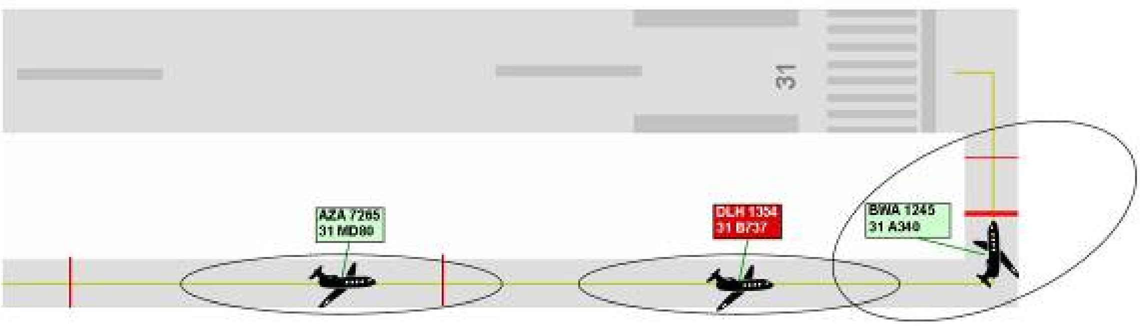


Figure 3-6: Safety Bubble Spacing Control – Stage 2 ALARM provided to ATCO.

3.3.4.1.5 'Next month': Advanced Safety Bubble Spacing Control

Preconditions:

- On-board implemented A-SMGCS functionalities:
  - moving map,
  - ground traffic display, and
  - onboard alerting.
- Ground implemented A-SMGCS functionalities:
  - surveillance,
  - conflict prediction, detection, and alerting[33];
  - routing.

Method Description:
In respect to the 'basic' safety bubble concept outlined in the previous section, the advanced concept foresees the provision of an alerting function also on-board through the implementation of an on-board safety net based on the 'bubble' concept. Therefore, in this case, both pilot and ATCO are provided with warnings and alarms in case of bubble conflictions.

In this context, the spacing task could be completely delegated to the flight crew as it is in visibility 1 and 2 conditions.

As a consequence, the ATCO should be able to instruct the traffic as s/he normally does in good visibility condition:

'AZA 7265 taxi to holding point RWY31 via TWY Tango number 3 on sequence preceding traffic DLH 1354 Boeing 737'.

Therefore, the application of advanced safety bubble spacing control should result in a further improvement of ground traffic management, with special reference to taxiing efficiency.

3.3.4.2 Visibility Condition 4

From an ATC perspective, there is no difference from visibility conditions 3 and 4, as the ATCO's situational awareness does not change over the two conditions. On the other hand, from the flight crew perspective, when visibility significantly deteriorates, the pilot ability to steer the aircraft is severely impaired as well as the ability to taxi.

To this respect, the implementation of specific on-board equipments, providing advanced A-SMGCS functionalities to the flight crew, can represent a valid means to overcome this limitation, as also stated in the A-SMGCS manual, section 3.5.14.10 [25]:

*'The system may need to be augmented by equipment in the aircraft or vehicle for operations in visibility condition 4***'.**

Specifically, the needed equipments are represented by the Moving Map and HUD Surface Guidance Symbology systems (refer to section 2.2 for more details). The implementation of these functions significantly improves the flight crew positional awareness and should allow pilots steering and taxiing without visual references outside the cockpit but basing exclusively on the electronic information provided by these systems. As a consequence of this, according to the ICAO definition of visibility conditions [25], visibility condition 4 can be brought back to visibility conditions 3.

[33] Including route conformance monitoring.

In this context, considering a scenario with a so-equipped traffic, Vis 4 operations could be managed as Vis 3 operations applying the spacing methods depicted in Section 3.3.4.1.

3.4 A-SMGCS Procedures using a Conflict Prediction, Detection and Alerting Services

The A-SMGCS conflict prediction, detection, and alerting service provides the ATCO with two types of alerts, named 'Information' & 'Alarm'.

- **T1 - INFORMATION**: When receiving an 'Information Alert', a potential dangerous situation may occur. The ATCO will use his/her skill and backgrounds to decide if, with remaining possible actions, the situation can be saved without using a too restrictive procedure (e.g. go around). If successful, there will be no Alarm and if not successful the Alarm will be activated and be presented on the traffic situation display.

- **T2 - ALARM**: When receiving an 'Alarm', it is said that a critical situation is developing and that an immediate action should be performed.

Introduce T1 and T2 and explain that it is certainly not the only way to proceed.

ICAO A-SMGCS manual [25] (section 3.4.5.7) states that 'every aerodrome has site-specific parameters and situations to be addressed'.

We propose a tentative and non-exhaustive list of conflict situations extracted from this manual.

3.4.1 Runway conflicts

1. Aircraft arriving to, or departing on, a closed runway

- An aircraft cleared to line-up on a closed runway shall trigger an INFORMATION coding

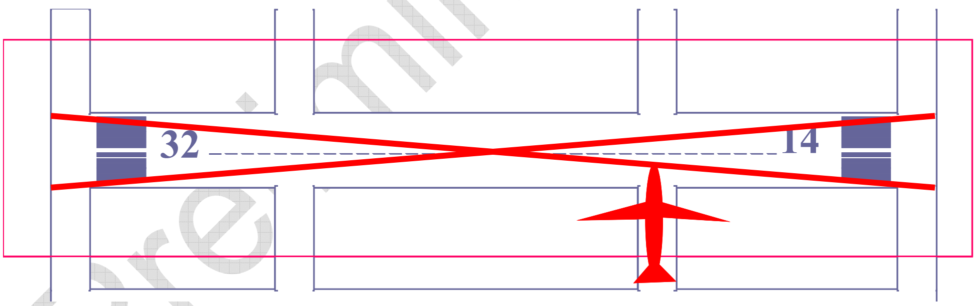


Figure 3-7: Aircraft cleared to line up on a closed runway

- An aircraft cleared to take off on a closed runway shall trigger an ALARM coding

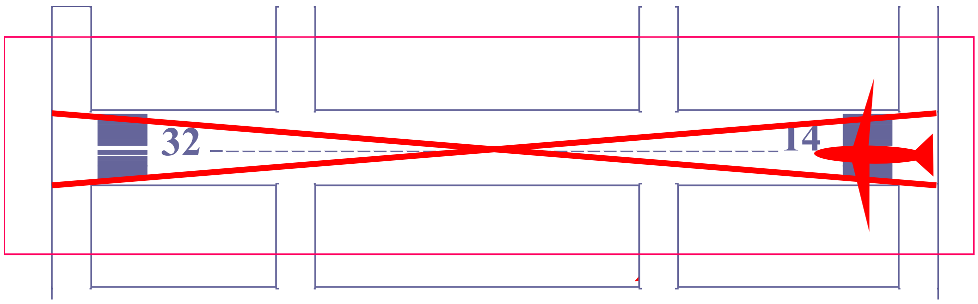


Figure 3-8: Aircraft cleared to take off on a closed runway

- An aircraft detected lining-up on a closed runway **without clearance** shall trigger an INFORMATION coding
- An aircraft detected taking off on a closed runway **without clearance** shall trigger an ALARM coding
- An arriving aircraft proceeding to a closed runway shall trigger an ALARM coding

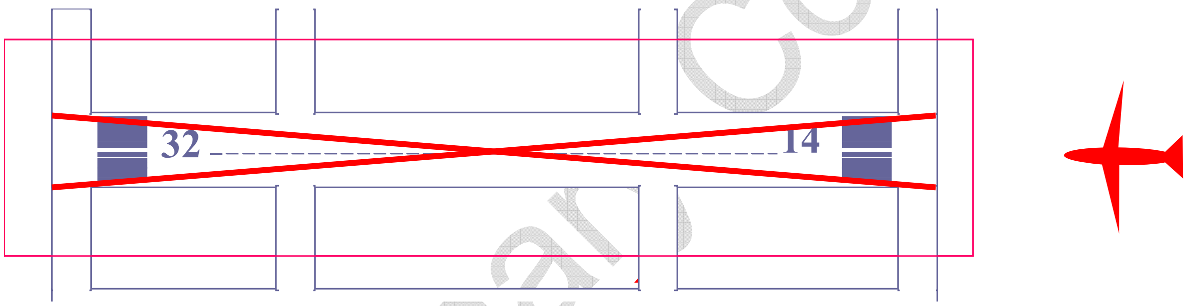


Figure 3-9: Aircraft landing on a closed runway

2. **Arriving or departing aircraft with traffic on the runway (including aircraft beyond the runway-holding positions)**

- An aircraft cleared to take off with traffic on the runway protection area shall trigger an ALARM coding

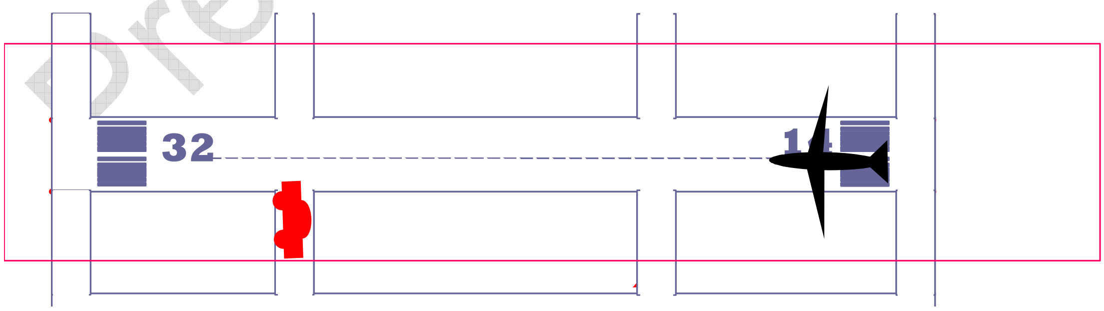


Figure 3-10: Departing aircraft with traffic on the runway protection area surface

- An aircraft detected crossing or lining up **without clearance** with traffic on the runway protection area shall trigger an INFORMATION coding
- An aircraft detected taking off **without clearance** with traffic on the runway protection area shall

trigger an ALARM coding

In these cases the departing aircraft is confronted with movement cleared to line up, cross or taxi on runway ahead of its current position.

- An aircraft cleared to take off with a movement cleared to line up, cross or taxi ahead shall trigger an ALARM coding
- An aircraft detected crossing or lining up **without clearance** with a movement cleared to cross, line up or taxi shall trigger an INFORMATION coding
- An aircraft detected taking off **without clearance** with a movement cleared to cross, line up or taxi shall trigger an ALARM coding

In these cases, we have a sequence of departing aircraft.

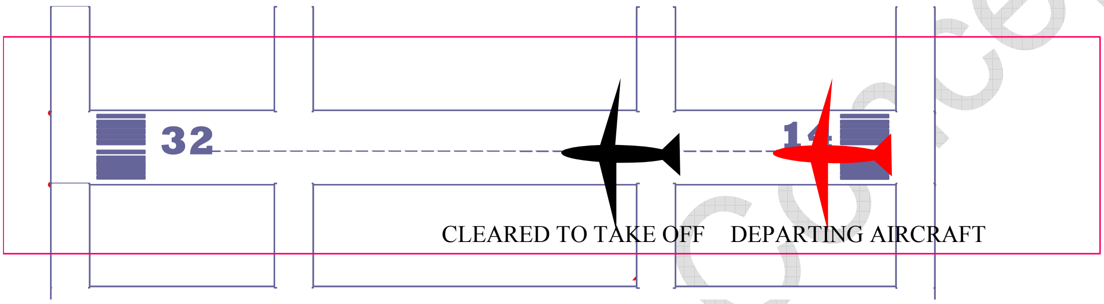


Figure 3-11: Departing aircraft with aircraft cleared to take off ahead

- An aircraft cleared to take off with an aircraft ahead cleared to take off shall trigger an ALARM coding
- An aircraft detected crossing or lining up **without clearance** while an aircraft ahead is cleared to take off shall trigger an INFORMATION coding
- An aircraft detected taking off **without clearance** while an aircraft ahead is cleared to take off shall trigger an ALARM coding

In these cases there is a movement detected on the runway protection area (RPA) while an aircraft is arriving.

- An aircraft < T1 from threshold with a movement on the RPA shall trigger an INFORMATION coding
- An aircraft < T2 from threshold with a movement on the RPA shall trigger an ALARM coding

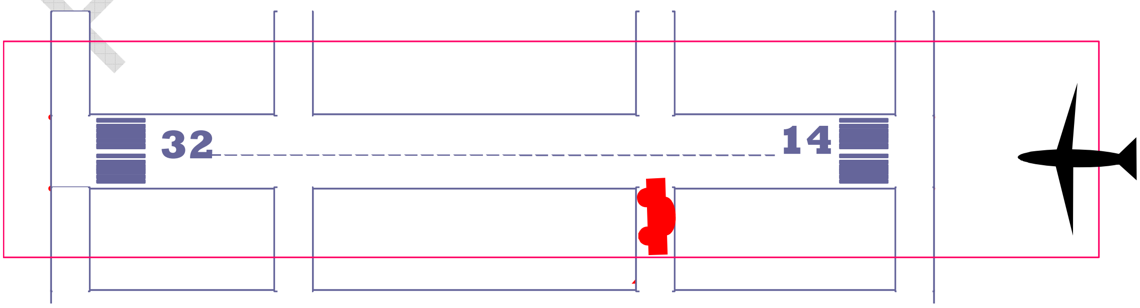


Figure 3-12: Arriving aircraft with traffic on the runway protection area surface

These cases encompass every event of arriving aircraft with a movement cleared to cross, line-up or taxi on runway.

- A movement cleared to cross, line-up or taxi on a runway while an aircraft < T1 from threshold shall trigger an INFORMATION coding
- A movement cleared to cross, line-up or taxi on a runway while an aircraft is < T2 from threshold shall trigger an ALARM coding

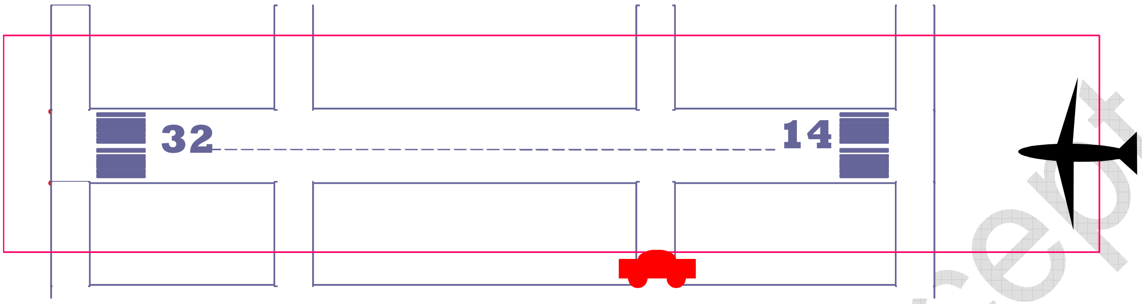


Figure 3-13: Arriving aircraft with traffic cleared to enter the runway protection area surface

- An aircraft cleared to land and < T2 from threshold while an aircraft is cleared to take off shall trigger an ALARM coding
- An aircraft detected landing and < T1 from threshold while an aircraft is cleared to take off shall trigger an INFORMATION coding
- An aircraft detected landing and < T2 from threshold while an aircraft is cleared to take off shall trigger an ALARM coding

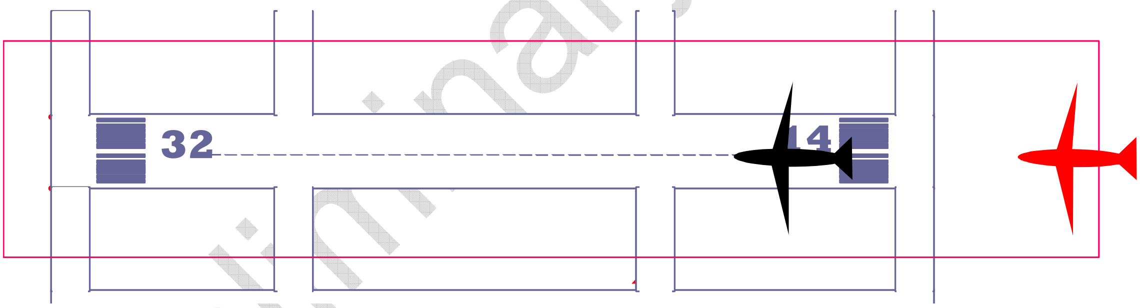


Figure 3-14: Arriving aircraft preceding aircraft predicted not to have vacated the runway

3. Arriving or departing aircraft with moving traffic to or on a converging or intersecting runway

The management of converging or intersecting runways depends very much from one airport to another. This case was not described in the current document.

However, the proposed concept of alerting should allow to easily describe the case of converging or intersecting runways.

4. Arriving or departing aircraft with opposite direction arrival to the runway

A departing aircraft proceeding to a runway 'opposite direction' than the one in force shall trigger the following alerts:

- An aircraft cleared to line-up on a runway 'opposite direction' shall trigger an INFORMATION coding
- An aircraft cleared to take-off on a runway 'opposite direction' shall trigger an INFORMATION coding
- An aircraft detected crossing or lining-up on a runway 'opposite direction' **without clearance** shall trigger an INFORMATION coding

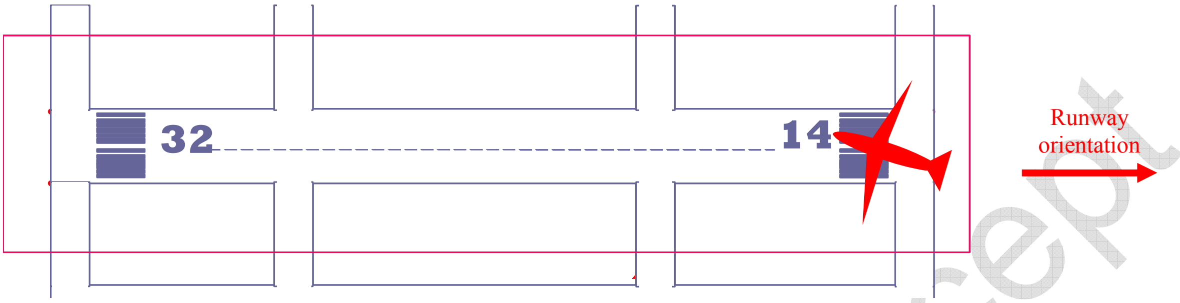


Figure 3-15: Aircraft detected lining up opposite direction

- An aircraft detected taking off on a runway 'opposite direction' **without clearance** shall trigger an ALARM coding

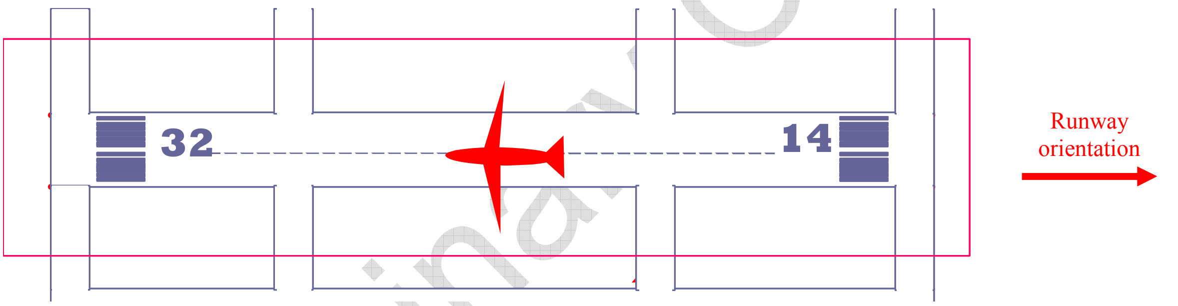


Figure 3-16: Aircraft detected taking off opposite direction

- An arriving aircraft with other traffic departing or landing on the same runway strip, opposite direction shall trigger an ALARM coding

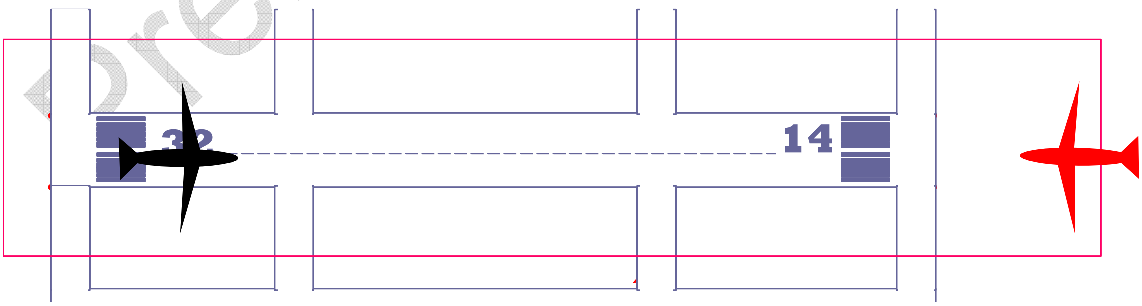


Figure 3-17: An arriving aircraft with other traffic departing or landing on the same runway strip

5. Arriving or departing aircraft with traffic crossing the runway

This case has been regrouped with case 2 **Arriving or departing aircraft with traffic on the runway (including aircraft beyond the runway-holding positions)**.

6. Arriving or departing aircraft with taxiing traffic approaching the runway (predicted to cross the runway-holding position)

The notion of prediction has been taken into consideration by checking the clearance input and by defining a runway protection area.

7. Arriving aircraft exiting runway at high speed with converging taxiway traffic

As long as the convergence happens on runway, this case is handled by Runway Incursion Monitoring Systems.

8. Arriving aircraft with traffic in the sensitive area (when protected)

This case has been regrouped with case 2 **Arriving or departing aircraft with traffic on the runway (including aircraft beyond the runway-holding positions)**.

9. Aircraft exiting the runway at unintended or non-approved locations

In general there is neither expressed intention nor approval from the ATCO regarding the runway exit used by an aircraft. There cannot be conformance monitoring without prior agreement (or clearance).

However, one could think about the side of runway to use to exit (left or right side) which may change depending on the parking. In this case, we could have the following rule:

- An aircraft detected exiting the runway on the wrong side should trigger an INFORMATION coding.

It requires the exit side to be input by the ATCO (or defined in the settings).

10. Unauthorized traffic approaching the runway

A movement entering the runway protection area without clearance triggers an ALARM.

11. Unidentified traffic approaching the runway

- An unidentified movement entering the runway protection area shall trigger an INFORMATION coding

3.4.2 Taxiway conflicts

The lack of experience in taxiway traffic management combined with the absence of ground separation standards lead to reduce the scope of taxiway conflicts to route conformance and few particular cases.

1. Aircraft on a closed taxiway

The restricted area incursions only concern incursions by an aircraft (not vehicles) into an area where the presence of an aircraft or a vehicle is permanently or temporarily forbidden.

- An aircraft entering (or predicted to enter) a restricted area shall trigger an INFORMATION coding

- An aircraft to be cleared to enter a restricted area shall trigger an INFORMATION coding

2. Aircraft approaching stationary traffic

Triggering of alerts for such cases was tried during EMMA and has faced a lot of conceptual and technical issues.
Operationally, aircraft approach stationary traffic every day on every airport without that being a hazardous situation (queue of aircraft on runway ramp access…). Besides, there is no operational definition of spacing between movements on the ground, except in low visibility conditions if block wise control is applied.

3. Aircraft overtaking same direction traffic

It is very common to have queue of aircraft on taxiways. However, the operational probability and hazard induced by an aircraft overtaking same direction traffic is very low.

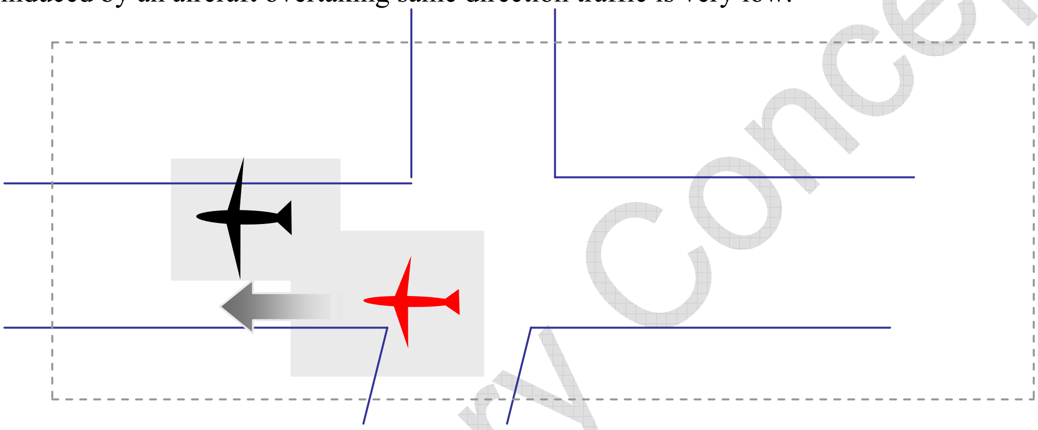


Figure 3-18: Aircraft overtaking same direction traffic

In case the taxiway has two lines on which aircraft can taxi, this should not be an issue (triple line at Paris-CDG). If the taxiway has only one centreline, an aircraft overtaking same direction traffic deviates from its assigned route. This is route conformance monitoring.

4. Aircraft with opposite direction traffic

This case will not be handled in EMMA2 because of a lack of maturity of conflict prediction algorithms. EMMA2 restricts to clearance and route conformance monitoring on taxiways.

5. Aircraft approaching taxiway intersections with converging traffic

Single aircraft approaching taxiway intersections could trigger an alert based on the routing information (taxi route conformance monitoring). Surrounding traffic will be considered to predict conflicts only if it is concerned by the routing function, i.e. subject to routing and thus to route conformance monitoring algorithms.

6. Aircraft taxiing with excessive speed

Heterogeneous speed is a factor of complexity in the traffic flow. Even though some speed regulations exist, the speed of an aircraft is generally left to pilots' decision.
Setting a high speed limit on taxiways should help detecting hazardous behaviour.

- An aircraft detected taxiing with excessive speed shall trigger an INFORMATION coding.

The speed limit requires to be set up high enough so that the number of nuisance alert is particularly low.
In this case we restrict the limitation to aircraft, because the relevance of monitoring vehicles speed on taxiways is questionable.

7. Aircraft exiting the taxiway at unintended or non-approved locations

This case is regrouped with case 8 **Unauthorised traffic on the taxiways**. It is covered by the notion of conformance monitoring.

- A movement deviating from its assigned route shall trigger **at least** an INFORMATION coding

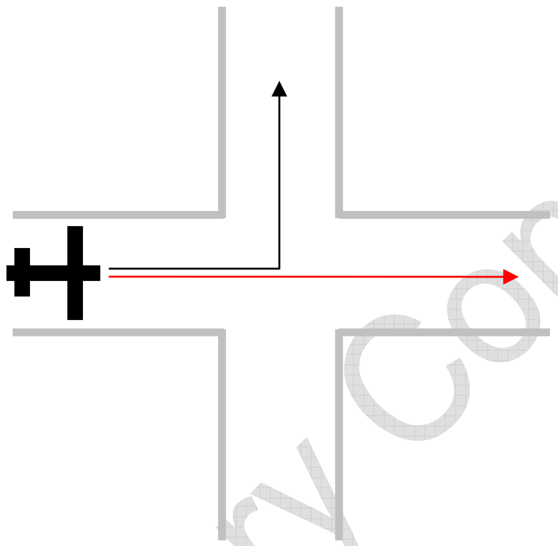


Figure 3-19: Aircraft deviating from its assigned route

Such an alert can be combined with other alerting situations. The coding triggered is thus **at least** an information coding.

Such an alerting requires to define a deviation parameter associated with the precision of surveillance.

8. Unauthorised traffic on the taxiways

This case is regrouped with case 7 **Aircraft exiting the taxiway at unintended or non-approved locations**. It is covered by conformance monitoring.

9. Unidentified traffic on the taxiways

On a theoretical point of view, a traffic not identified by A-SMGCS on the manoeuvring area should trigger an INFORMATION coding. However, the fact that all movement driving on such an area are not equipped yet lead to restrict this alerting to the runway protection area. Its extension to the whole manoeuvring area depends on the level of equipment of the fleet on the concerned airport.

10. Crossing a lit stop bar

This case is handled in the runway set of cases: an aircraft crossing a lit stop bar enters the runway protection area.
One can expect that the switching on and off of stop bars will be done by the ATCO through its electronic stripping system (automatic link to the clearance).. Considering this, one ensures the

consistency between the state of the stop bar (lit or off) and the clearance provided (cleared to cross, line-up…). Thus, a movement crossing a lit stop bar performs an action without clearance.

3.4.3 Apron/stand/gate conflicts

As mentioned in § 2.1.2.1.1, most of the apron conflicts will not handled in EMMA2.

1. Aircraft movement with conflicting traffic

The definition of a conflict on a taxiway is difficult because there is no standard separation. On apron, it is even more complex since some movements are in contact (baggage truck with aircraft…). This case will not be assessed in EMMA2.

2. Aircraft movement with conflicting stationary objects

As mentioned above, there is no way to distinguish a conflict from regular traffic.

3. Aircraft exiting the apron/stand/gate area at unintended or non-approved location

This case is considered as taxi route conformance monitoring, since the taxi lanes leading to an apron/stand/gate area can be considered easily considered as taxiways.

4. Unidentified traffic in the apron/stand/gate area

Traffic in the apron/stand/gate area is not necessarily identified by A-SMGCS. Most of the traffic in this area is not in contact with the control tower (not even radio equipped). This case is then discarded from the concept.

3.5 A-SMGCS Procedures using an A-SMGCS Routing Services

3.5.1 Manual Routing (R1)

In manual routing, the route is mentally produced by the ATCO without any support of automation but the A-SMGCS HMI allows to input the route and to assign it to a specific movement. Different alternatives for route assignment (input in the system) might be used (non exhaustive list):

a) via the A-SMGCS traffic situation 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;
b) via keyboard (alphanumerically) into the electronic flight strips (EFS);
c) via speech recognition.

Compared to current way of working, it is foreseen that manual input of routes in the system could provide additional workload to the ATCO. It is too early to prejudge the way by which the ATCO might input the taxi route in the system (technical aspects and human factors guidance are required for acceptability purpose). But any solution which would result in increasing their workload and reducing their flexibility in the route assignment has to be avoided.

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

Another workload 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[34].

3.5.2 Semi-Automatic Routing (R2)

In a semi-automatic mode, some support of automation is given by using advisory information to compute the most suitable taxi route based on a valid path from the start point to the intended end point taking into account available constraints such as local standard routes, local limitations for taxiways (LVP conditions), type of aircraft, closed taxiways, restricted areas, obstacles, temporary hazards; intermediate waypoints, and time constraints (e.g. blocked runways that are known in advance).

The proposed route is assigned by the ATCO by an appropriate input device, either via a target on the traffic situation display or via the Electronic Flight Strip.

If the route proposal does not match to the ATCO's intention the ATCO can easily select another suitable route. If no route proposal is accepted by the ATCO, s/he has to generate it manually.

Departure Flight:
Independently of the associated HMI, the system should propose the most suitable route, which takes into account all constraints. This initial proposal could be made to the clearance delivery position[35] on request. The Clearance Delivery Controller could have the possibility:

a) To visualise and electronically acknowledge or reject the route proposed by the system;
b) To assess constraints that have been taken into account for its determination;
c) To add specific constraints (for example related to taxiway intersections).

Once allocated the initial route and when a point to point data link environment is available, it could be transmitted to the cockpit as a preliminary information. In the cockpit the route could be presented on special onboard display in a graphical way. However, the route has not been cleared by the ground controller. The route transmitted by the clearance delivery announces the route to be expected to be cleared by ground and tower controller. The ground or tower controller would still have the possibility to modify the initial taxi route if necessary. If the initial taxi route information has been modified, an UPDATE message should be accompanied with the new route clearance to make the Flight crew aware of this modification.

Arrival Flight:
The system should be able to determine the most appropriate exit related to the most efficient (standard) taxi route to reach the final parking position. However, following (9830, §2.5.2.1), '*the routing function of an A-SMGCS should not constrain the pilot's choice of a runway exit following the landing*'. As a consequence, the routing system proposes the most appropriate runway exit that implies that the aircraft should not vacate earlier but allow the crew to vacate later if certain reasons would make it necessary. The initial taxi route could be provided in advance via data link to the pilot, at least before the aircraft passes the outer marker.

Re-routing of movements on the surface:
Re-routing of movements is an exception but occurs from time to time (e.g. after a route deviation, change of operational conditions, etc). Depending on the level of automation of the routing function, different procedural scenarios are conceivable. In any case, the routing function is able to compute a new valid route. Whether this new route has to be requested by the ATCO or whether the route is

[34] For more explanation to "route deviation alert" see "Conflict Prediction, Detection, and Alerting Service" §2.1.2.1.1.
[35] If a clearance delivery control position is available always depends on how ATC is organised on a specific ATC Tower. Supplementary, the first ATCO in the departure loop (preferred is a non-executive Ground or Tower Controller) should take over this task.

adapted automatically and has only to be re-cleared by the ATCO (via voice or data link) depends on the maturity level of the routing function.

3.5.3 Automatic Routing/Planning (R3)

Compared to manual and semi-automatic routing where the assignment of routes would be carried out by the ATCO, the system in that case would automatically assign routes. However, the system would provide adequate information to enable manual intervention in the event of a failure or at the discretion of the control authority.

Some issues associated to this level of automation encompass:

a) The level of confidence (associated to system reliability) in the system to determine taxi routes taking into account all real-time constraints. Importance should be granted to avoid any assignment of unavailable route for any reason. The system should facilitate the introduction of updated information e.g. taxiway closed for a defined period of time due to work in progress.
b) In case of system failure or at discretion of the ATCO, manual intervention should be enabled.
c) As the system will need complete and reliable information to perform an efficient route assignment, the support of a planning function is needed. The planning function interacts with the routing function and other information resources to compute best start-up times, off-block times, based on flight plan information, calculated taxi times, weather information, surveillance and control function information.

3.5.4 Advanced Automatic Routing / Departure Planning (R4)

Departure planning deals with the tactical planning of runway usage taking into account the traffic mix of arriving and departing flights. This is performed by a departure management tool.

Currently ATCOs optimise the sequence of aircraft available quite before the holding point. However if an efficient planning tool would be available, it would be easier for him/her to alternate aircraft on diverging SIDs or tracks, as the tool assists the ATCO to make these aircraft available at the holding point at the right time.

Increasing the efficiency of the airport system is therefore possible by planning ahead the time aircraft will be at the holding point. This could be possible by measuring and analysing the push back and taxi times for combination of aircraft type, stand position, runway access, and weather conditions. This would lead to determine the ideal times to approve the start up and give the push back or taxi clearances, so that an optimal sequence of aircraft on the runway is achieved[36].

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 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 a Target Start-up Approval time (TSAT) 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.

[36] Airport/CFMU slot needs to be taken into account in all cases.

3.6 A-SMGCS Procedures to operate Ground Guidance Means

The guidance function of an A-SMGCS (ref. Doc 9830 [25]) should:

a) *Provide guidance for any authorised movement and be available for all possible route selections;*
b) *Provide clear indications to pilots and vehicle drivers to allow them to follow their assigned routes.*
c) *Enable all pilots and vehicle drivers to maintain situational awareness of their positions on the assigned routes;*
d) *Be capable of accepting a change of route at any time;*
e) *Be capable of indicating routes and areas that are either restricted or not available for use;*
f) *Allow monitoring of the operational status of all guidance aids; and*
g) *Provide online monitoring with alerts where guidance aids are selectively switched in response to routing and control requirements.*

The EMMA OSED document [5] has identified two logical steps for dealing with ATCO ground guidance services:

- **G1**: Manual switched ground guidance (G1), section 7.8.1;
- **G2**: Automatic switched ground guidance (G2), section 7.8.2.

3.6.1 Manual Switched Ground Guidance

Manual operation implies that 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.

A possible associated operating method for dealing with a taxi route assigned to an aircraft (once the respective taxi route clearance issued) is as follows: 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 will remain dark.

Benefits linked to the use of this service might be questioned. In particular, switch of segments operated manually might reduce capacity and safety as you don't monitor the traffic while switching segment(s)) and would induce high costs for airports to be equipped.

3.6.2 Automatic Switched Ground Guidance

Automatic switched ground guidance assumes that a taxi route displayed and accepted by the ATCO 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.

If and how such system can be used on the ground is not known, thus setting up associated procedures is considered as rather immature.

3.7 A-SMGCS Procedures using a TAXI-CPDLC service

3.7.1 Introduction

The EMMA2 operational design for TAXI-CPDLC, described in this chapter, is aligned with ICAO [35] [32] and the work of the EUROCONTROL CASCADE Operational Focus Group (OFG) [15]. The message set proposed by these two sources has been taken into account by the EMMA2 message set, but also additional potentially useful messages have been generated by EMMA2.

However, the EMMA2 validation activities would not be able to test all proposed options or the complete set of A-SMGCS TAXI-CPDLC messages. Moreover, a step by step approach is aimed to provide operational feedback on the most basic messages (cf. Figure 3-20). Nevertheless, with EMMA2 trials the basic messages can be supplemented by additional messages out of the overall EMMA2 message set. Which messages will be tested remains a decision of the test site authorities. In the end, EMMA2 TAXI-CPDLC validation results will feed back and improve the current operational and technical design of controller – pilot communication on the ground. The results and recommendations will feed the respective SP6 documents.

When defining a new kind of communication between the ATCO and the flight crew different characteristics of communication have to be considered, e.g.:

- Criticality (safety- or time critical vs. less safety- or time critical),
- Operational status (Information vs. clearances),
- Quantity of message elements per message (one vs. several),
- Party line effect (important or less important information for other flight crews).

Since the communication media ‘TAXI-CPDLC’ and ‘voice’ encompass different advantages and disadvantages, it is aimed that the best communication media is exploited for the different user needs on communication.

Operational benefits of data link communication on the cockpit side are already published rather well. E.g. in cockpit simulations and on-site trials in the BETA project [39] pilots spoke with one voice that they see a great safety and workload benefit to get the taxi route information via datalink. If this textual information would be accompanied by a graphical presentation on an onboard moving map it would additionally increase their situation awareness and decrease their workload. This has yet to be confirmed by EMMA2 trials. The preliminary reports from the BETA project also stated that they wish to get safety critical clearances like take-off, landing, and line-up clearances via voice.

Furthermore, in EMMA first phase, Airbus has gathered encouraging feedback from pilots during evaluations of the TAXI-CPDLC functions, concerning workload and situation awareness. Pilots were enthusiastic about the graphical presentation of the taxi routes on the onboard moving map. They advocated for an optional transmission of the routing information in a strategic phase, followed by the transmission of one complete or several segmented taxi clearances (depending on the airport configuration and ATC organisation) in the tactical phase, and possibly the transmission of taxi clearance revisions in a more time-critical phase. They considered that voice shall be kept for non-nominal and time-critical situations.

Experiences from the ATCO’s side referring data link communication for ground operations are rather limited. Possible benefits, e.g. a reduction of the ATCO’s workload or a reduction of the voice channel load, have been identified, but it has to be proven yet which operational design of a mixed environment of voice and data link communication meets best safety and efficiency aspects. The design of the pilot’s and ATCO’s HMI will play a key issue here. Even if TAXI-CPDLC is expected to take over non-safety and non-time critical routine communication only, the TAXI-CPDLC HMI design must allow the user to perform such routine communication in a safe and efficient way.

If this is achieved the following benefits can be expected (§2.15, Part I, [32]):

'*a) increased safety by reducing the potential for erroneous receipt of messages;*
b) reduction of voice-channel congestion;
c) reduction of radiotelephony workload for both the pilot and controller;
d) increased communication availability;
e) reduction of late transfer of communications;
f) reduction of re-transmissions caused by misunderstood communications;
g) increased flexibility in handling ATC communication tasks;
h) more efficient use of airspace due to more time being allocated to providing a better service to user aircraft, rather than to routine communications tasks;
i) reduced controller stress/memory burden; and
j) reduced controller communication time.'

Beside the expected benefits following anticipated constraints have been identified both for the ATCO and for the flight crew:

- Anticipated Constraints by the ATCO
  - Increased visual attention needed to operate TAXI-CPDLC that will reduce the time to monitor the traffic situation
  - Increasing workload by excessive input requests (mouse clicks)
  - Tactical control and train of thoughts is endangered by deferred response times (latency), e.g. pushback and taxiing communications are often time critical…
  - A mix of aircraft handled by TAXI-CPDLC or voice could lead to additional workload and communication errors
  - A mix of voice and data link communication for different phases of a single flight could lead to confusion and communication errors
  - Automatic generation and indication of the taxi route not flexible enough to meet the users' needs

- Anticipated Constraints by the flight crew
  - Increased need for internal crew communication
  - Different procedures, either brand specific or Airport specific, could lead to the flight crew's confusion

Mix of Voice and Data Link:
As voice communication will be available in parallel to data link, the alternative use of both communication means has to be considered. Several reasons lead to a mix of voice and data link clearances:

- During the time when TAXI-CPDLC is introduced, not all aircraft will be equipped. Thus the ATCO will have to handle some aircraft via voice and others via TAXI-CPDLC.
- At least in a first time, TAXI-CPDLC shall be used only for less time- and safety critical ground clearances. This means, that in the course of controlling a specific aircraft some clearances will be given via TAXI-CPDLC and others via voice.
- When an operational exception occurs, communication will revert to voice. Especially a safety-critical event, which requires immediate action, or negations or the provision of additional information, will lead to the immediate use of voice.

A requirement with a mix of voice and data link is that the human end users must retain the ability to follow the operational course and thus to track the clearances given, in order to guarantee the required situation awareness. This applies especially to the ATCO, who has to control several aircraft at the same time and in different phases of ground operations. In a conventional SMGCS this is guaranteed through the ATCO who notes a given clearance on the paper flight strip, and the pilot who notes it on the kneepad. With an A-SMGCS, clearances, given by TAXI-CPDLC, will be ‘in the system’, and thus should be able to be displayed so that the human operators can track them.

The other aspect is, that several A-SMGCS services, like monitoring the conformance of aircraft to given clearances, and the planning/routing services, must know which clearances have been given to an aircraft, in order to perform their functionality. Therefore the HMI must provide means to enter every clearance into the system, whether given by TAXI-CPDLC or by voice.

HMI:
Interaction will change when using TAXI-CPDLC with respective advantages and disadvantages. Exchanging information via text messages requires entering the message on the sender’s side, and reading the messages on the recipient’s side. Sending and reading would further shift the operator’s perception towards a visual one, which is already more loaded than the acoustic perception for instance. On the other hand the compilation of messages can be automated or efficient means to select and compose message elements can be applied. The strict use of a standardized message set in English will avoid misunderstandings by non-native speakers. Messages available in a system can be checked by the recipient and recalled and analysed in detail later on, and thus relieve from the necessity to note them on paper sheets.

The implementation of TAXI-CPDLC in an A-SMGCS requires the availability of other automated high-level services, which release the ATCO as far as possible from the manual composition of messages, in order to avoid the respective workload and keep the times for manual inputs into the system as low as possible.

The automatic provision of the next clearance to be given and the time when this shall happen by a routing/planning service, and more over the automatic generation of taxi routes by the route planning service, will be the basis for the TAXI-CPDLC service. This requires the services to comprise a well tuned operational model, which considers the course of control at the specific airport. The generated next clearance then will be presented at the HMI, where the ATCO can trigger the transmission. S/he can also reject it and select a clearance more suitable for his/her intentions. Moreover, means to answer a pilot’s request or to give information are required, also accomplished by message selection.

The presentation of a clearance to the ATCO at the HMI may happen either in text format, or by a graphical symbol or, for a taxi clearance, also in graphical format with the route and the clearance limit (holding point) depicted (cf. also §2.4).

The selection and thus entry of a clearance shall be possible also when a clearance shall be given via voice, in order to record a given clearance for tracking (situation awareness) purposes, and to feed other services with the required information.

The respective HMI functionality can be accomplished e.g. via an electronic flight strip display, which on each flight strip shows an indication for the next clearance to be given, and provides a means to select the flight strip, to check the contents of the clearance in detail, to trigger the transmission or to select an alternative clearance. Graphical information concerning the cleared taxi route can be displayed on the A-SMGCS traffic situation display.

In a nutshell, a TAXI-CPDLC service allowing an effective use requires a high degree of integration with other A-SMGCS services or functions.

3.7.2 General ICAO Principles

The following general procedures are taken from the ICAO Doc 9694 ‘Manual of Air Traffic Services Data Link Applications’ (PART IV, [32]) describing commonly agreed CPDLC principles that should also be mandatory for TAXI-CPDLC operations:

1.1 Controller-pilot data link communications (CPDLC) is a means of communication between controller and pilot, using ***data link for ATC communication****.*

1.2 The CPDLC application provides air-ground data communication for ATC service. This includes a ***set of clearance/information/request message elements*** *which correspond to voice phraseology employed by ATC procedures. The controller is provided with the capability to issue level assignments, crossing constraints, lateral deviations, route changes and clearances, speed assignments, radio frequency assignments, and various requests for information. The pilot is provided with the capability to respond to messages, to request clearances and information, to report information, and to declare/rescind an emergency. The pilot is, in addition, provided with capability to request conditional clearances (downstream) and information from a downstream ATSU. A ‘free text’ capability is also provided to exchange information not conforming to defined formats. An auxiliary capability is provided to allow a ground system to use data link to forward a CPDLC message to another ground system.*

1.3 Controllers and pilots will use CPDLC in conjunction with the existing voice communication. It is expected to be ***used for routine or frequent types of transactions****. Although initial implementation is intended to conform to existing procedures, it is anticipated that future evolution of the system and procedures will result in the* ***greater automation*** *of functions for both aircraft and ground systems.*

1.4 The introduction of CPDLC does not affect the principle that there is ***only one controlling authority for a given aircraft at a given time****. The capability for the pilot to request downstream clearances does not affect this principle.*

1.5 Sending a message by CPDLC consists of selecting the recipient, selecting the appropriate message from a displayed menu or by other means which allow fast and efficient message selection, and executing the transmission. The received message may be displayed and/or printed. A message sent by a downstream ATSU will be distinguishable from a CPDLC message sent by the current ATS unit.

1.6 CPDLC may be used to ***remedy a number of shortcomings of voice communication****, such as voice channel congestion, misunderstanding due to poor voice quality and/or misinterpretation, and corruption of the signal due to simultaneous transmissions.*

1.7 Implementation of CPDLC will significantly change the way pilots and controllers communicate. The ***effect of CPDLC on operations should be carefully studied*** *before deciding the extent to which voice will be replaced by data link.*

1.8 The following aspects of CPDLC should be taken into account in considering its application and in defining procedures:

- *a) the* ***total time*** *required for selecting a message, transmission of the message, and reading and interpretation of the message;*
- *b) the* ***head-down time*** *for the pilot and controller; and*
- *c) the inability of the pilot to monitor other data link transmissions to and from other aircraft in the same area of operation.*

4.2 When a required response is not successfully delivered, the message initiator is responsible for querying the state of the response via an appropriate medium.

4.3 Except when the clearance specifies otherwise, execution of a clearance received via data link may begin upon ***pilot initiation*** *of the action which sends the acceptance message.*

4.4 Messages are to be reviewed and responded to in a timely manner upon receipt. If messages are queued, they are to be ***displayed sequentially*** *in the order of receipt, with the exception that messages with a higher urgency will be displayed first.*

4.5 When a controller or pilot communicates via voice, the response should be via voice.

4.6 If a data link message which requires a closure response is subsequently negotiated via voice, an appropriate ***data link closure response*** *for that message will still be initiated.*

Note.— Even though a voice response may have been provided, a data link response is necessary to ensure ***proper synchronization of ground and aircraft systems****.*

4.7 Pilot CPDLC message alerts may be suppressed during take-off, approach, and landing. If a message requiring an alert is received during the suppression period and is still pending at the end of the period, the alert will be re-initiated when the suppression period is over.

4.8 Procedures should accommodate mixed data link and voice capability.

4.9 Aircraft operating procedures for CPDLC should be ***consistent and independent*** *of the flight phase or ATS facility.*

4.10 A CPDLC message should contain ***no more than two message elements*** *with the 'route clearance' variable.*

7.4 Transfer of the CPDLC link can be carried out in ***conjunction*** *with the transfer of voice ATC communication.'*

3.7.3 EMMA2 TAXI-CPDLC Principles and Procedures

Taking into account these ICAO principles, the respective service descriptions in this document (§2.1.2.1.3 and §2.2.5), and the D-TAXI OSED [15], following additional EMMA2 principles or options for TAXI-CPDLC operations are introduced:

a) In accordance to ICAO Doc 9694 (PART IV, §1.7, [32], see above), also EMMA2 aims to KEEP IT SIMPLE as much as possible since it is the first step with the transition from voice to data link communication on ground.

   Note: Ground control supported by TAXI-CPDLC is not in operation today. It lacks maturity and experiences of the users. Therefore operating procedures shall be developed in a simulation environment step by step by starting with a very simple set of data link messages, which are less safety- and time critical. This does not exclude that the complexity of TAXI-CPDLC messages or procedures must not be extended later on, provided that they are still safe and efficient.

b) When TAXI-CPDLC is used, voice communication will always be the back-up solution: As soon as something is deviating from normal operation and the situation is time critical, e.g. UNABLE responses or even no response, the communication switches back to R/T, because voice communication is the most practical means to resolve a non-nominal or even safety critical situation safe and efficiently. Normal TAXI-CPDLC responses are 'WILCO', 'ROGER', and 'STANDBY'. Non-nominal responses are, 'UNABLE', an ERROR message, or no response.

c) Each data link message transmission is followed by a logical (technical) acknowledgement (LACK), i.e. the sender gets an immediate feedback that the message has completely been transmitted and is available on the recipient's display.

d) In addition to the logical acknowledgement an operational acknowledgment (here 'WILCO' or 'ROGER') is required for each clearance or information. 'Information' messages are messages that do not require or grant any actions (e.g. EXPECT ROUTING TO… VIA …). They are acknowledged via a ROGER response. 'Clearances' require an action of the crew and have to be acknowledged by a 'WILCO' or 'UNABLE' response. The operational acknowledgement tells the ATCO that the pilot has read and understood the clearance and will comply with it.

e) In the cockpit while the aircraft is on the ground, normally, the Crew Member 2 (CM2) is performing the data link communication, while the CM1 is steering the aircraft.

Note: To get the CM 1 informed about data link information and clearances, additional onboard communication has to be implemented (for more details see §3.10.11).

f) In the cockpit, incoming data link message, that require an immediate reaction, should be accompanied with an aural signal. Non-time critical messages (information) are not accompanied by an aural signal.
In the Control Tower, incoming data link messages are not accompanied by aural signals but by visual attention catchers within the electronic flight strips.

g) The ATCO will perform the data link communication via electronic flight strips (EFS), the CM2 via the appropriate onboard data link control unit.

h) The call-sign of the aircraft does not need to be an element of a TAXI-CPDLC message since current data link technology is able to provide an unambiguous addressable point to point data link connection.

Note: There is still a risk that TAXI-CPDLC messages are sent to an unintended aircraft, which would be caused by a human error (ATCO input error by selecting the wrong EFS).

i) The complete taxi route (including intermediate and final holding points) is generated by a semi- or fully automated routing function (compare §2.1.3), knowing the starting point and end point (including all necessary additional information, like de-icing request or NOTAM information). The computed taxi route is presented to and validated by an ATCO and transmitted to the cockpit via data link. The complete taxi route may include 'clearance' elements (TAXI TO …), 'information' elements (EXPECT ROUTING TO… VIA …), and 'clearance limits' (HOLD SHORT OF …), and eventually some 'free text', e.g. QNH information, if required by local procedures.

Note: The 'automatic generation of a taxi route' is a severe operational requirement in order to prevent the executive ATCO to type in messages or to compose messages by selecting message components.

j) As an option, a preliminary taxi-out route **information** could already be transmitted earlier, when the aircraft is still at the gate (stand), at the time when the flight crew is receiving the departure clearance (usually 10 to 15 minutes before the aircraft is ready for start-up). The transmitted taxi route at this time will not be a clearance but information only. It is not supposed to replace a clearance, i.e. it is an 'expected' taxi route, transmitted by the message 'EXPECT ROUTING TO… VIA…'. If the flight crew accepts the expected taxi route, a 'ROGER' message is sent back to the Clearance Delivery Controller (CDC). Such a preliminary taxi route could eventually be included in the DCL. When the actual taxi route clearance deviates from the prior sent taxi route information, the flight crew shall be informed by an UPDATE or REVISE message.

Note: With this option it is assumed that an expected taxi route remains valid with a high probability until it is cleared finally. For Airports, which do not operate with standard taxi routes or where the taxi routes are hardly predictable, the transmission of an expected taxi route would be less useful. On the other hand, a preliminary taxi route information that remains valid with a reasonable probability would help the crew to assess and cross-check the taxi route in advance and in a less time-critical phase of the flight. The later received corresponding clearance can be assessed and acknowledged faster and helps to shorten the latency of the 'taxi request – taxi clearance – and acknowledgement – start taxiing' turn around process.

k) When the aircraft is ready for start-up, push-back or taxiing out, the CM2 requests the respective clearance from the Ground Executive Controller (GEC). This is done by data link. By the related EFS the GEC is informed about that request. The taxi route is displayed in the EFS and in addition to that could be graphically linked with the traffic situation display. After the TAXI REQUEST the GEC validates and clears the computed taxi route by data link.

Note: Independently of having received a request from the CM2 or not, the ATCO is always able to deliver a clearance.

l) The CM2 and the CM1 verify the operational contents of the clearance and CM2 transmits a response message via data link (usually a 'WILCO' response). This response closes the data link communication loop.

m) As soon as the expected taxi route or the already cleared taxi route is not valid anymore, a taxi route revision is needed. The revision of a taxi route can be requested by the flight crew or initiated by the GEC.

Note: A taxiing aircraft is a time- and safety critical event. When taxi route revisions would be necessary while the aircraft is taxiing EMMA2 proposes to envisage two steps to perform taxi route revisions: by voice only by a first step, and later on by datalink. This is in contradiction to the D-TAXI OSED [15]. *However, if operational tests show that such a taxi route revision can be generated immediately and automatically, safely and efficiently transmitted, and cleared via data link, voice communication could be accompanied or even replaced by data link communication. This would be beneficial from the point of view that the technical system, both onboard and on ground, is informed about the clearance and remains in the decision and monitoring loop.*

n) Before the landing phase, the pilots would appreciate receiving an ATC proposed runway exit that is at least in accordance to the individual aircraft performance, weight category (WVC), load, runway/tarmac status (wet/dry/icy, etc.), final stand, and the current traffic situation. The proposed time frame to uplink such a message is thought to be 20-10 min before landing. The routing function would generate an optimal runway exit and an expected inbound taxi route including the final stand information. This information could be transmitted via data link in advance of the landing by the 'EXPECT ROUTING TO… VIA…' message. When the flight crew accepts the expected taxi route, a 'ROGER' message is sent back to the TEC.

Note: The information must be provided before the aircraft has started the final approach phase – depending on the relevant flight phase inhibition logic for D/L in order to enable the flight crew to acknowledge it after having assessed the feasibility performance of such an exit, to set the auto brake system accordingly and to brief each other about actions to be performed upon landing. The ATC exit proposal would not be compulsory for the flight crew – however it remains an ATCO's recommendation not to vacate at an earlier exit. For safety reasons the flight crew may always decide on a later exit.

Both the recommended exit and the taxi-in route information, which is originated by GEC, should be given in advance, but the aircraft at this time would still be under control of APP. This raises the question how the information can be transferred to the cockpit. Three proposals have been focussed:

1. *Via downstream operations according to the ATN downstream concept, which would require that the pilot logs in to the downstream control unit (Tower Control). This would however result in additional workload to the flight crew, what should be avoided in this phase of a flight.*
2. *Directly via APP control uploading the preliminary taxi route information by data link, which would save an additional logon for the flight crew, but the taxi route information would have been passed from ground control to APP, or*
3. *Via the Airline Operations Centre, which already uploads the stand information 30 min in advance. Even here, the taxi-in route would have been transmitted from Ground control to the AOC.*

For the time being there isn't enough information available to support or withdraw each of the proposed option. Future research will provide more information.

o) After handover to the GEC, the inbound taxi route is cleared by data link as already described with the outbound taxi clearance (cf. k) above).

p) Handovers could be initiated by a manual or automatic data link transmission: 'CONTACT [unit name] [frequency])' informing the flight crew about the radio frequency information of the next control position. The initial call with the next control position however should be performed by voice in order to guarantee that the R/T contact has been established as a back-up solution.

The following Figure 3-20 shows an example for the basic EMMA2 TAXI-CPDLC communication process to be implemented at the test sites of Prague and Milan Malpensa.

Event	ATCO	CM2
Expected Taxi-out route (optional)		REQUEST TAXI ROUTING INFORMATION
	EXPECT ROUTING TO RWY 06 VIA TAXIWAY R L F E	
		ROGER
Start-up clearance		REQUEST START-UP[37]
	START-UP APPROVED	
		WILCO
Push-back clearance		REQUEST PUSHBACK[38]
	PUSH-BACK APPROVED	
		WILCO
Taxi out clearance		REQUEST TAXI[39]
	TAXI TO HOLDING POINT E FOR RWY 06 VIA TAXIWAY LEFT R L F HOLD SHORT OF RWY 31/13 *NEXT EXPECT TWY F E*[40]	
		WILCO
Expected Taxi-in route (optional)		REQUEST TAXI ROUTING INFORMATION
	EXPECT ROUTING TO STAND 22 VIA TAXIWAY A M N LEFT	
		ROGER
Taxi in clearance		REQUEST TAXI[41]
	TAXI TO STAND 22 VIA TAXIWAY A M N LEFT	
		WILCO

Figure 3-20: Example for the basic EMMA2 TAXI-CPDLC Concept

The complete EMMA2 TAXI-CPDLC message set for Toulouse trials can be found in the EMMA2 'A-SMGCS Technical Requirements Document' (2-D112b_ATR-AIR)[42].

3.7.4 Composition of EMMA2 TAXI-CPDLC Message

A TAXI-CPDLC message has the following characteristics:

- it consists of one or more message element(s).
- Up to 5 message elements in a single message are allowed.

[37] Clearance requests can either have the structure "REQUEST (clearance) CLEARANCE" as defined by ICAO or "REQUEST (clearance)" as defined by EMMA2. These alternatives have been chosen for different test purposes.
[38] Clearance requests can either have the structure "REQUEST (clearance) CLEARANCE" as defined by ICAO or "REQUEST (clearance)" as defined by EMMA2. These alternatives have been chosen for different test purposes.
[39] Clearance requests can either have the structure "REQUEST (clearance) CLEARANCE" as defined by ICAO or "REQUEST (clearance)" as defined by EMMA2. These alternatives have been chosen for different test purposes.
[40] Airbus does not support the use of the NEXT EXPECT message element together with the taxi clearance, which could increase the risk of confusion between expect information and clearance. The "expect routing information" should be sent apart from the real taxi clearance.
[41] Clearance requests can either have the structure "REQUEST (clearance) CLEARANCE" as defined by ICAO or "REQUEST (clearance)" as defined by EMMA2. These alternatives have been chosen for different test purposes.
[42] At the time of the publication of the SPOR document, the 2-D112b was not published yet.

- There are message elements (e.g. TAXI TO (parameter)), which can be used for a stand-alone clearance. Others can be used only as a part of a clearance (e.g. VIA TAXIWAY (parameter)) and others can be used for both (e.g. CONTACT (parameter)).
- A message element consists of one or more ‘keywords’, which define the type of the clearance or message, and one ore more parameters, which indicate the required information. Depending of the type of message element, parameters can be mandatory or optional.

Example (Taxi Clearance with four message elements):

TAXI TO STAND 241R
VIA TAXIWAY R2 F3 E4
WHEN REACHING TAXIWAY F3
CONTACT GROUND NORTH 118.65

In the following an example for Prague is given, which shows the operational use of TAXI-CPDLC clearances for an inbound flight.

The aircraft has landed on RWY 24 and exited at TWY E. On the way to stand 22 it has to cross RWY 13/31 and thus to stop at the intersection.

Optionally before landing the following route information will be given by ATC:

EXPECT ROUTING TO STAND 22
VIA E F G B A

The first taxi clearance after landing would be:

TAXI TO STAND 22
VIA E F
HOLD SHORT OF RWY 13
NEXT EXPECT VIA F G B A

Close to the intermediate holding point the pilot gets the voice clearance to cross runway 13/31 and to contact *Ground*.

The following taxi clearance for the rest of the route would be:

TAXI TO STAND 22
VIA F G B A

If no intermediate holding point is required, since RWY 13/31 is non-active, only one clearance with just two message elements is necessary. HOLD SHORT OF can be omitted, since the destination matches the clearance limit:

TAXI TO STAND 22
VIA E F G B A

The currently standardised ICAO CPDLC message set is intended for en-route only. However, several message elements are comprised, which can be used also for taxi applications.

3.8 A-SMGCS Procedures using Electronic Flight Strips (EFS) (incl. handover)

Electronic flight strips (EFS) represent a basic tool for presenting an air traffic situation within the airspace of responsibility and its vicinity in a simplified and schematic way to ATCO to enable him/her to build-up a mental picture for the purpose of easy, quick and errorless decision making in the process of provision of air traffic control, flight information, alerting service and in the context of ATCO’s subject relevant main and supporting tasks and subtasks.

Since ATC was developed, paper flight strips, where each of them represents one single aircraft or one formation flight, have changed their appearance, few methods of handling them was developed as well. Strips can be sorted by time, level or flight status, colours or arrow symbols are involved to distinguish the direction of flight. Also strip format differs from user to user, anyhow it is always broken down into fields containing pre-processed necessary flight data and offering space for note making. Strips are located in flight progress board, divided into bays. Strip bays are used for separating strips into logical clusters, position of each inside shows its actuality (active, pending, etc.).

The system of paper flight strips is generally very cheap and instinctive environment for ‘analogue’ human being which gives to air traffic controller a good tool to support his/her decision making. It is very easy to handle, finding appropriate information is fast, system gives big flexibility in changing of desired order and enables notepad and archive function. A possibility of ‘touching it’ gives to human being better confidence to what s/he is doing. On the other hand, this system has its own limits. To keep system valuable, it has to be continuously updated. Having more then 10 flights active (subjective view, traffic complexity and using culture dependant), system becomes not fully updated due to lack of time of controller which should be spent on this task, therefore it becomes formal, therefore it becomes useless. Huge production of paper prints for the same flight due to ETO or FL changes during coordination between neighbouring units becomes critical. Many strips on the table create a risk of ‘loosing a picture’.

After an introduction of surveillance technology into the civilian ATC, paper flight progress strip system became a supporting tool in ATC control loop. But it still plays the role of a back-up system in case of surveillance system failure even it is very difficult to recover in high complex environments.

Flight strips offer an environment which provides functionality, such as:

- Decision making tool
- Notepad
- Archive

With EFS also new added value through the automation should be addressed:

- Continuous automatic real time data update based on actual target’s position
- Clearance manager
- Clearance monitor
- Uplink command transmitter for TAXI-CPDLC
- Downlink message receiver for TAXI-CPDLC
- Safety net tool – e.g. wake vortex separation assurance, taxi route adherence monitoring
- Stopbar trigger switch etc.,

Two concepts can be produced – electronic flight progress strip system (EFS) or stripless environment (SLE) offering data interaction through the target label. Both systems have advantages and disadvantages. EFS offer automated functions and act as semi-independent back-up in case of situational display failure even if with degraded functionality. On the other hand, it requires additional space at CWPs and division of perception of ATCO amongst three environments (outside view, surveillance systems, EFS) with significant head-down time. SLE offer higher comfort to ATCO in handling the system, but it gives limited possibilities for data input. In case of failure, no data are available to support decision making process unless systems are reasonably doubled. With EMMA2, only EFS will be addresses. Anyhow, system has to be designed such to enable as easiest transition from paper environment as possible and it shall be perspective for further development.

As it was said at the beginning of this chapter, EFS is to be understood as a prerequisite in allowing the use of higher automated functions, which A-SMGCS can easily support and which ATCO can benefit from. It is not part of A-SMGCS, it is a viable separate control tool with high level of interoperability.

The following example describes in general the handling of EFS at three ATCO working position at Prague Control Tower: Clearance Delivery Controller (CDD), Ground Executive Controller (GEC, and the Tower Executive Controller (TEC).

CDD position

1. Upon request for start-up, select the appropriate pre-planned flight from 'CDD PENDING' menu by single click on 'CALL SIGN'. Strip moves from 'CDD PENDING' menu to 'CDD EDIT' menu and changes its background colour into active status. If needed, a VFR flight without flight plan can easily be created by a single click on 'FPL' icon at 'CDD EDIT' menu and fill all the mandatory fields.
2. Issue the ATC clearance according to data displayed at the strip at 'CDD EDIT' menu. Single click on 'DEP' button after instructing the aircraft to contact Ruzyně-Ground. Strip moves from 'CDD EDIT' menu to 'CDD ACTIVE' menu and is 'copy-pasted' to 'GEC DEP PENDING' menu at GEC position. After its activation at GEC position, strip changes its background colour into passive status. This action represents that the GEC has assumed control of the flight.

GEC position (outbound flight)

1. Upon request for push-back, select an appropriate flight from 'GEC DEP PENDING' menu by single click on 'PUSH' button. Strip moves from 'GEC DEP PENDING' menu to 'GEC DEP ACTIVE PUSH' menu in case of push-back procedure will follow and changes its background colour into active status. In case of taxi-out procedure will follow, strip remains untouched at 'GEC DEP PENDING' menu.
2. Upon request for taxi, single click on 'TAXI' button. Strip moves from 'GEC DEP ACTIVE PUSH' menu or 'GEC DEP PENDING' menu to 'GEC DEP ACTIVE TAXI' menu and changes its background colour into active status. Strip is 'copy-pasted' to 'TEC DEP PENDING' menu at TEC position. After its activation at TEC position, strip changes its background colour into passive status. This action represents that the TEC has assumed control of the flight.

TEC position (outbound flight)

1. Upon initiation of R/T with the flight, single click on 'CALL SIGN'. Strip moves from 'TEC DEP PENDING' menu to 'TEC DEP ACTIVE' menu and changes its background colour into active status.
2. Single click on 'L-UP' button when instructing to line-up. Strip moves from 'TEC DEP ACTIVE' menu to 'RWY DEP' block. Background colour remains active status. RWY occupation warning is given by A-SMGCS.
3. Single click on 'TKOFF' button when instructing to take-off. Strip moves from 'RWY DEP' block to 'AFTER DEP' menu. Background colour remains active status. Take-off time is assigned by A-SMGCS. Implemented time parameter erases the flight from progress board.

TEC position (inbound flight)

1. Upon initiation of R/T with the flight, single click on 'C-APP' (Continue Approach) in case landing clearance can not be issued. Strip moves from 'TEC ARR PENDING' menu to 'TEC ARR ACTIVE' menu and changes its background colour into active status.
2. Single click on 'C-LND' button when landing clearance is issued. Strip moves from 'TEC ARR ACTIVE' menu or 'TEC ARR PENDING' menu to 'RWY ARR' block. Background colour remains active status. RWY occupation warning is given by A-SMGCS.
3. Single click on 'GO-AR' button when instructing to execute missed approach. Strip moves from 'RWY ARR' block back to 'TEC ARR PENDING' menu. Background colour changes into passive status.

4. Single click on ‘LDNG’ button when aircraft has vacated the runway. Strip moves from ‘RWY ARR’ block to ‘TEC AFTER ARRIVAL’ menu. Background colour remains active status. After its activation at GEC position, strip changes its background colour into passive status. This action represents that the GEC has assumed control of the flight. Implemented time parameter erases the flight from progress board.

GEC position (inbound flight)

1. Upon initiation of R/T with the flight, single click on ‘CALL SIGN’. Strip moves from ‘GEC ARR PENDING’ menu to ‘GEC ARR ACTIVE’ menu and changes its background colour into active status.
2. Single click on ‘BIN’ button when flight no longer needed. Implemented time parameter erases the flight from progress board.

3.9 A-SMGCS Procedures related to Failures and Contingencies

This section describes contingencies procedures to adopt when the A-SMGCS services cannot be applied due to system failures. This section does not aim to be exhaustive in identifying all possible failures that could happen; only the most apparent failures and their most apparent contingencies procedures are outlined.

3.9.1 Surveillance Service

When the identification function fails, the automatic track labelling no longer operates correctly and the aircraft/vehicle identification is either not presented or incorrect.

The loss of identification could have several causes including human error (e.g. input of incorrect information in the transponder) or technical failures like:

- Individual aircraft/vehicle failure of co-operative tool (e.g. transponder), or
- A ground control system failure (e.g. multilateration).

The loss of the label does not necessarily mean the ATCO has lost the identification of the aircraft/vehicle because the mental picture and flight strips are still available.

The impact that such loss will have on safety and ATCO workload mainly depends on:

- The number of aircraft/vehicles without identification;
- The traffic density;
- The visibility conditions including night or day;
- The aerodrome layout;
- The control of aircraft/vehicles referring mainly on display information.

If identification is lost, the surveillance service should indicate to the user that the service failed to provide ID information for one or more movements. When the ID information was available primary but not updated for a while, the ID can be kept with the target but should be dropped after five seconds when not getting updated automatically. Otherwise the service would prevent providing trustful information which is not.

As a contingency measure/back up system, the procedural control using the flight strips should always be kept updated and procedures already established by ICAO in Doc 4444 [35] section 8.10.2.3 are applied for a single movement or the whole traffic if the service fails completely.

3.9.2 Conflict Prediction, Detection, and Alerting Service

The prediction and detection of conflict situations and providing alerts to the ATCO is an additional safety net feature. It does not require changing current procedures.

> In case of system failures of this service the A-SMGCS should indicate to the ATCO that the service is partly impaired or even cannot be used anymore. The ATCO is thus aware of but procedures do not have to be changed.

When an alert is triggering the ATCO's attention to a conflict situation, that needs immediate reaction to be solved, the ATCO assesses the conflict situation and issues adequate instructions to resolve it in a safe way. Thereby the ATCO's assessment of the conflict situation contains the verification of the severity of the conflict situation. For that reason s/he is comparing different sources of traffic information:

- the Tower outside view,
- cameras,
- the flight strips (electronic or paper),
- the traffic situation display (TSD).

In case of inconsistent automatic traffic information or if there is a mismatch between displayed traffic situation and visually acquired traffic situation the ATCO can disregard the alert situation. Such nuisance alerts are mostly caused by false targets[43]. Nuisance alerts are not fully avoidable but have to be kept to a minimum to allow a trustful and safe conflict prediction, detection, and alerting service.

If an alert is triggered, but traffic situation cannot be monitored by the Tower using outside view or cameras due to reduced visibility, the ATCO has to trust the automation without a verification check. The ATCO shall immediately initiate appropriate actions to solve the conflict situation. After having solved the conflict situation the ATCO should investigate the reasons for the alert in order to prevent further potential conflict situations caused by the prevailing circumstances.

3.9.3 TAXI-CPDLC Service

When TAXI-CPDLC is used, different potential failures have to be considered:

A first concern refers to the correctness and completeness of the data link message transfer. This concern has been solved on a technical basis:

> Each data link message transmission is followed by a logical (technical) acknowledgement (LACK), i.e. the sender gets an immediate feedback that the message has completely been transmitted and is available on the recipient's display.

But since TAXI-CPDLC is a very immature service there are several other concerns, which are very vague up to now, for instance at the current day it is hard to define 'time critical situation' with respect to data link communication. For that reason a general fall back procedures should be applied:

> As soon as something is deviating from normal operation and the situation is time critical, e.g. UNABLE responses or even no response, the communication switches back to R/T, because voice communication is the most practical means to resolve a non-nominal or even safety critical situation safe and efficiently. Normal TAXI-CPDLC responses are 'WILCO', 'ROGER', and 'STANDBY'. Non-nominal responses are, 'UNABLE', an ERROR message, or no response.

[43] False targets covers the events where the surveillance element outputs reports from targets which are not operationally significant (or even not there at all).

In order to guarantee that voice communication can always be used as a back up solution, the initial call with the next control position should be performed by voice.

Pilots must permanently monitor the respective control frequencies. Voice R/T instructions from the controller shall overwrite any TAXI-CPDLC instruction.

3.9.4 Sectorisation, Transfer of Control, and Coordination Service

Backbone of this service is electronic flight plan information that can easily be processed, edited, shared and handed over with / to other controller working positions or even other control centres. Those data are frequently presented by electronic flight strips (EFS) that are often designed in accordance to the former printed flight strips. Concerns rising up when EFSs fail to provide correct information, fail to allow editing flight plan information, or even getting lost completely.

A practicable back up solution would be a redundant flight strip system, having the former printed flight strips as a parallel information stream. When EFSs fail the current printed strips are handed to the respective controller working positions. When EFSs do not fail within its lifetime the printed paper compagnons can be neglected.

3.10 A-SMGCS Operating Procedures for Flight Crews

3.10.1 Preamble

The following references in regard to flight crew procedures from official publications are quoted; overall ICAO (§2.3, note, [25]) states that :

‘When using A-SMGCS, pilots remain responsible for the safety and control of aircraft’

1. ICAO A-SMGCS Manual [25]
§1.2 g) *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;’

§3.2.2.6 *Under the conditions envisaged for the operation of an A-SMGCS, the system and its operators will be required to accept a high level of responsibility for spacing between aircraft. There will still be options for the pilot to maintain visual spacing under some circumstances, but there will also be operational conditions when pilots will not be able to see conflicting traffic and obstructions’*

§3.5.14.6 *The operational procedures of A-SMGCS should be standardized, with no significant variations, at all aerodromes where all weather operations are conducted.*

2. JAR-OPS 1 [38]
§1.2.10 *Establishment of procedures:*

(a) An operator shall establish procedures and instructions, for each aeroplane type, containing ground staff and crew members’ duties for all types of operation on the ground and in flight.

3. ICAO DOC 8168 Vol 1 and 2 (PANS-OPS) [36] [37]
No specific guidance for flight crew operating procedures is given.

3.10.2 Introduction

Several on-board services to be used by flight crews associated to primary services have been identified in section 2.2:

- Airport moving map,
- Surface movement alert,
- Ground traffic display,
- Traffic conflict detection,
- TAXI-CPDLC,
- Braking and steering cues,
- HUD surface guidance symbology,
- Automated steering,
- Ground- air database upload..

Warning: as the majority of these services are under definition at different levels of evolution, the maturity level of potential procedures (when possible) or even initial guidance for use is subject to debate. At this stage of the EMMA2 project, they have to be carefully considered as preliminary guidance. Consolidation work shall be performed during EMMA2 validation activities and in the results and recommendation reports.

Therefore for most of the services in section 2.2. the following subsections contain descriptions on how to use the respective system rather than how to operate them.

3.10.3 Transponder Operating Procedures

The following analysis has been done essentially on the following documents:

- ICAO Annex 10 Aeronautical Telecommunications, Volume 4, Surveillance Radar and Collision Avoidance System, up to Amendment 77
- ICAO A-SMGCS Manual [25],
- DOC 8168 Vol 1 section III-1-3-(i) [36],
- EUROCONTROL Draft A-SMGCS Operating Procedures Edition 1.5, [17],
- EUROCONTROL Mode S-Transponder, Edition 1.1 [22],
- EUROCONTROL Leaflet Transponder Operating Procedures Mode S Multilateration, [22],
- EMMA1 D1.3.5u_ORD-Update [6].

The use of a traffic situation display, instead of the present visual activity of the ATCO for aerodrome control procedures, has introduced the notion of 'identification' of traffic on that display. Today the surveillance systems in use or expected to be used in a short term are based on Mode-S transmission of identification data.

It is mandatory for air traffic control to identify the aircraft ID prior to give traffic information, instructions, or clearances to this aircraft.

For that purpose, flight crews should input data and set their transponder box in accordance to the published Transponder Operating Procedures [22]. This introduces some changes from the present flight crew operating procedures which are described in the following section.

Note: A review of presently used transponder panels in cockpits from different manufacturers revealed that no standard in symbology can be stated, i.e. STBY, XPDR, AUTO, ON; there are models with combined and split ATC and TCAS functionalities in use; this detrimental effect has already produced shortcomings in A-SMGCS life environment thus aircraft being not 'visible' (transponder remains in STBY) or too early (transponder already operating at the gate/stand before taxi/push-back request) or too long (transponder operating after arrival at the *gate/stand) and this fact is of ongoing concern. It is therefore essential that airline operators clearly develop checklists taking into account relevant symbology of their type specific transponder panels.*

3.10.3.1 Departure

At the gate / stand

Select STBY

- Enter the discrete mode A code received from ATC;
- According to aircraft equipment, enter the Airline 3-letter ICAO designator, followed by the 4 digit flight identification character (numbers, letters or both) through the MCDU of the FMS or the Transponder Control Panel.

These operations will prepare the transponder to start exchanging data with no delay when needed.

<u>Note</u>: *Aircraft visible on the gate prior to push back do not follow published Mode S transponder procedure. At the gate the transponder should be off (e.g. STBY selected), activated on the request for push back/taxi whichever is earlier.*

On requesting push back / taxi (whichever is earlier)
Select XPDR (or equivalent) and AUTO when available

- At this time the aircraft ID (used as the call sign by ATC) will be displayed on the traffic situation display giving the opportunity to ATC to process the mandatory identification procedure (and verification of data's) before using the radar data.

When Lining Up
Select TA/RA

- TCAS should not be selected before receiving the clearance to line up to ensure that the performance of systems based on SSR frequencies (including airborne TCAS units, SSR and A-SMGCS) is not compromised.

3.10.3.2 Arrival

When Still on the Runway
Keep TA/RA selected

After Vacating the Runway
Select XPDR or equivalent and keep AUTO + TA/RA STBY when available

- There is a need that the transponder remains able to exchange data with the A-SMGCS system. However, to ensure that the performance (including airborne TCAS units, SSR and A-SMGCS) is not compromised, TCAS should be deselected when vacating the runway.

Fully Parked on Stand
Select STBY

- When STBY is selected, the transponder is not transmitting or replying to interrogation. The discrete Mode A code given to that particular flight can be recycled for other flights.

3.10.3.3 Miscellaneous

These procedures cover other needs than departure and arrival (e.g. an aircraft needs to move on a taxiway between two stands it seems that the conspicuity code will be 2000 in order to avoid confusion at airports where mode S will be used for the airside and 1000 used only when ‘identity’ is verified).

3.10.4 Basic Procedures

Designation of Crew Members

The Multi Crew Concept (MCC) regulates the organization of work and task sharing on the flight deck. In general a 2-pilot crew will operate modern transport aircraft in commercial operations. The designation of crew members is as follows:

- CM 1 is the pilot who is sitting in the left hand cockpit position, in most cases s/he is the commander of the respective flight; exceptions are supervision flights for pilots who are in the upgrading to become commanders or training flights
- CM 2 is the pilot who is sitting in the right hand cockpit position, normally s/he is the First Officer (FO) or the assisting pilot when the aircraft is on ground
- CM 3 is the pilot who is sitting in the middle seat or at the flight engineers position if provided.

  There might be more than three pilots on board e.g. relief pilots for ultra-long routes, check- or training pilots.

Besides this seat related distinction of crew members the node Pilot Flying (PF) and Pilot Not Flying (PNF) -also called as Assisting Pilot- is used to allocate and differentiate tasks and duties when the aircraft starts take-off roll until slowing down to taxi speed after landing., i.e. when the aircraft is ‘in flight’. Naturally PF can be CM 1 or CM 2 whilst the remaining pilot would act as PNF.

The PF shall focus his/her attention primarily on the control of the aircraft in flight; whenever other activities or special events may prevent the PF from fulfilling this task, s/he shall hand over to the PNF with the call ‘you have control’. The PNF shall confirm takeover with the reply ‘I have control’.

The PNF shall assist the PF, by e.g.

- Supervising the PF
- Performing R/T
- Inputs to the auto flight control system when on manual flight, e.g. entries in the MCDU of the FMS or DCDU if provided
- Paper work
- Other assisting tasks on command of the PF

ATC-Clearances

No flights requiring an ATC clearance shall commence take off without such clearance. All ATC clearances, altimeter settings and RWY in use must be read back including the full call sign.

Standard phraseology must be used. Wording must be clear, precise and unmistakable. A written record of the initial SID (if a data link clearance has been received the appropriate printout), any significant re-clearance and deviations from planned figures must be made on the Operational Flight Plan.

The commander is responsible to ensure that:

- Application of received clearances is safe with respect to terrain clearance during climb / descent and en-route;
- Compliance with the provisions of a clearance will not violate other regulations (e.g. night curfew).

Pre-flight procedures in regard to A-SMGCS

Operations in A-SMGCS environment require a functional Mode-S transponder which is redundant, i.e. two independent sets are provided. They can be switched to XPDR/ON/AUTO/STANDBY/OFF - switch settings depend on individual mark/model, ref. Note in section 3.10.3 – by the flight crew.

For more details on Transponder Operating Procedures, refer to section 3.10.3.

Lookout during ground operations
The flight crew has to maintain a constant lookout and avoid other traffic during all phases of flight. Radar service advisories may be helpful in detecting other traffic[44]. Any activity diverting attention (e.g. paper work, MCDU/DCDU/FMS insertions) must be reduced to a minimum within an airspace deemed critical by the flight crew, e.g. whilst taxiing in- and out.

Designation of tasks during Taxi
Most airlines require the CM 1 to steer the aircraft on the ground; such clear task designation is derived from legal considerations in case of a taxi incident: The commander, normally CM 1, is responsible for the safe operation of his/her aircraft.

S/he shall concentrate on steering the aeroplane, while the CM 2 should concentrate on navigation and has to give advice from taxi chart/electronic means, including heading information and visual cues to be expected. In the context of A-SMGCS relevant systems and functions the CM 2 will be the pilot manipulating control panels in the cockpit, handling data link, reading and checking settings and messages.

Surface markings must be observed. If there is any doubt about the position, the aeroplane shall be stopped and ATC or apron control shall be informed. Holding position markings and signs must not be passed without clearance. Lighted stop bars must not be crossed. In the absence of such markings or visual aids the aeroplane shall hold at least 70m clear of the active runway.

Before take-off the active flight crew, i.e. CM 1 and CM 2 (and CM 3 if on duty), must verify by all possible means that the aeroplane is lined-up at the correct position.

Best practises shall be used to avoid runway incursions, ref. ICAO DOC 9870 [34].

Commencement of Take-Off Roll
The take-off should be commenced at the beginning of the runway. If performance permits, flight crews should refrain from sharp turns during line-up in order to avoid unnecessary stress on wheels and tyres. Depending on performance intersection take-offs are permitted.

Conditional Line-up clearances may be accepted provided the flight crew pays highest attention to their contents and meanings.

On closely spaced runways and when VFR traffic is in sight of the flight crew TCAS should be selected to TA only in order to avoid undesired RA's.

Initial Communication with ATC after take-off
Initial communication with ATC should be established by the PNF as soon as practicable, as instructed or as prescribed by local ATC procedures - but not before 'gear lever up' and 400ft AGL.

Parking procedures
When entering any parking or holding position the assisting flight crew member calls out as soon as possible the markers, signs, indicators, etc. – applicable to such position - s/he has identified. The flight crew member manipulating the aircraft, normally CM 1, confirms verbally if in his/her assessment s/he is in consensus with such a call, otherwise s/he shall indicate clearly his/her findings.

[44] Reminder: regarding departure aircraft, TCAS should not be selected before receiving the clearance to line up. For arrivals, TCAS should be deselected when vacating the runway ref. Section 3.10.3.

3.10.5 Supplementary Procedures

Preamble

Pilot considerations have been depicted in ICAO DOC 9830 [25] and A-SMGCS Manual DOC 9476 [33] under 14 desirable requirements.

EMMA D.1.3.1u OSED document (§2.2, services to flight crews) [5] identified and mapped these requirements on on-board functions, i.e. airport moving map, surface movement alert, ground traffic display, traffic conflict detection, TAXI-CPDLC, braking and steering cues, HUD surface guidance symbology, automated steering, ground- air database upload.

Four logical expected steps (e.g. A1[45], A2, A3 and A4) for flight crew services have been identified [5]:

- **A1**: Airport Moving Map , Surface Movement Alerting, Braking and Steering Cues for landing roll ;
- **A2**: Ground Traffic Display, Taxi-CPDLC , Braking and Steering Cues during taxi operations, Ground Air Database Upload;
- **A3**: HUD Surface Guidance ;
- **A4**: Automated Steering.

Important Remark:

Since most of these functions are not yet implemented and/or under research, the following list of new/modified/changed flight crew duties and tasks linked to these functions is necessarily incomplete and based on current knowledge of relevant systems. A continuous update and feedback by validation activities during the EMMA 2 project is essential.

Therefore the description in the following sections shall not be utilized as a tool to develop Standard Operating Procedures (SOPs) but rather as preliminary guidelines.

3.10.6 Airport Moving Maps (AMM)

Airport Moving Maps will supplement the out-of-window situation assessment by displaying own ship position with respect to aerodrome geographic locations, ground based facility locations in proximity of the aircrafts' position and the particular aerodrome elements referenced in the ATC instructions. The navigation task for the flight crew will thus be primarily based on visual observation. In particular ICAO Doc 9830 [25] section 1.3.9 states that *'for low visibility conditions, the pilot may need suitable avionics, such as a moving map, to monitor progress and compliance with the assigned route'*.

The Moving Map function will enhance the situational awareness of the flight crew and ease navigation on airports, especially at complex, congested and unfamiliar locations. The overall level of flight safety when manoeuvring on the ground will be increased considerably.

Different and independent control interfaces allow the PF and the PNF:
- to interact on the airport navigation, especially for map annotation and map moving.
- to configure (zoom, display mode) the different displays. It is essential that one pilot after the other will manipulate on his/her control panel, never both at the same time head down.

It is considered essential that - at least for the beginning period - redundant maps and charts on paper, on electronic format or other redundant means are available and used for crosscheck purposes, most probably derived from the identical data source/database supplier, and used by the flight crew. If an electronic format is used, the manufacturer/database supplier shall guarantee the reliability and

[45] Airborne 1 (A1) … Airborne 4 (A4)

integrity of such data. Specific NOTAMS shall be provided by the manufacturer/database supplier for last minute changes or deviations which become active in between the time period of validity of the relevant on-board database and the next AIRAC cycle; it is anticipated that in the beginning of the operational use of the AMM an automatic upload of the Ground-Air Database will not be fully functional thus requiring flight crews to manual insert/amend/alter the onboard database.

It is assumed that the AMM function will be integrated in the manufacturer specific flight instrument system, i.e. scalable like for the Navigation Display (ND); thus it is believed that no dedicated cockpit display will be provided.

Taxiing solely thanks to the electronic picture might be conceivable, from an airline perspective however beyond relevant operational issues for taxiing in low visibility conditions because the responsibility for the commander to avoid a possible collision would not be changed in the foreseeable future – ref ICAO A-SMGCS Manual [25] section 2-3: *'Note. — When using A-SMGCS, pilots remain responsible for the safety and control of aircrafts'.*

On the other hand certification related to the airport moving map for autonomous taxiing would represent a costly challenge compared to its use some days in the year.

Note: For the beginning of TAXI-CPDLC (see section 3.10.11) the graphical presentation of taxi routes will not be available thus pilots will have to interpret and transform text messages presented on the MCDU/DCDU in a virtual mapping picture where to taxi.

The following procedures are based on the availability of a dual, redundant AMM.

Departure Flights

- Normal Visibility Conditions:

Instead of using the airport taxi map as the primary source for navigation and orientation the AMM picture will provide a consistent, scalable graphical representation of possible taxi routes to the take off position. Standard Operating Procedures (SOPs) for flight crews will have to be developed how to manage safe taxiing based on visual observation and information derived from the AMM in a multi-crew complement.

- Low Visibility Conditions:

As the AMM will only supplement the navigation task for the flight crew taxiing an aircraft to the take off position/to the gate or parking position after landing in low visibility conditions taxi speed will be necessarily slower compared to normal visibility conditions; however taxi speed is expected to be faster than without using the AMM.

The commanders responsibility of the respective flight to avoid a possible collision with another aircraft/obstacle/object will not change in the near future irrespective of new services proposed under A-SMGCS technology.

Depending on the day to day level of accuracy, integrity and reliability of the AMM, flight crews will more and more base their navigation task on the electronic information thus minimizing queries to ATC where to taxi. Navigational errors will diminish significantly. .

Notes:
1. It must be emphasized that safety critical information, e.g. the location and the status of stop/clearance bars shall be provided consistently.
2. On-board backup maps and charts or equivalent, e.g. on backup electronic means, shall supplement moving map displays and must be used by flight crews, especially under LVO conditions, unless the AMM function is certified as sole means of compliance.

- Relevant Operations:

Relevant operations for the use of the AMM include preliminary cockpit preparation, cockpit preparation, taxiing and take-off operations:

- ✓ **Preliminary cockpit preparation**: check maps/charts (on paper or in electronic format) available on board for redundancy (CM 2);
- ✓ **Cockpit preparation**: EFIS/equivalent electronic flight instrument control panel: select the lowest range, review airport details on the AMM display; then crosscheck content with maps/charts or equivalent means (CM 1/2);
- ✓ **Taxiing-out**:
  - All visibility conditions: steer the aircraft along the cleared taxi route by visual observation (normally CM1); crosscheck present aircraft position, taxi route and runway entry point with AMM display (normally CM2). The stated task allocation between CM1 and CM2 may vary depending on company specific operational rules and procedures.
  - In case the cleared taxi route is not displayed as a picture on the AMM display the CM 2 will have to read the TAXI-CPDLC transmitted text message on the MCDU; CM 1 will crosscheck the content on his/her MCDU and will confirm verbally his/her approval and consent.
  - Low visibility conditions: call out relevant information contained on the AMM display - e.g. taxiway designators, stop bars, crossings, intersections and runways in close proximity (CM 2); crosscheck callouts by visual reference or by reference to redundant maps and charts or equivalent means (CM 1).
- ✓ **Take-off**: check correct take off point and runway designator by visual observation and crosscheck it with AMM display (all flight crew members on active duty in the cockpit have to perform this task independently from each other)

Arrival Flights

- Normal Visibility Conditions:

Instead of using the airport taxi map as the primary source for navigation and orientation the AMM picture will provide a consistent, scalable graphical representation of possible taxi routes after landing.

It is expected that the map picture of the airport layout with relevant taxi routes after landing will be available in flight; it is assumed that this map picture together with a crosscheck on conventional maps and charts or equivalent means will provide a reliable data source for the approach briefing. Depending on environmental conditions /runway surface/local procedures, the envisaged runway exit/turn-off point shall be clearly identified; such items are part of the approach/landing briefing.

Standard Operating Procedures (SOPs) for the flight crew will have to be developed; special emphasis shall be put on how to manage safe taxiing after landing based on visual observation and information derived from the AMM under a multi-crew complement.

- Low Visibility Conditions:

Low Visibility Operations at most airports have prescribed exit routes where and how to leave the active runway, e.g. by illuminated green centre line lights. Thus it is believed that the AMM function will have a minor importance compared to other means on how to identify such routes; however when the aircraft has arrived at the respective exit point the AMM will play the identical role as taxiing for take off (see above) under LVO conditions. On quite a number of airports today such visual guidance is not installed on all taxiways and parts of the apron; the navigation task to be performed by the flight crew is therefore sometimes extremely difficult, therefore the AMM will play a major procedural role.

- Relevant Operations:

- ✓ **Approach preparation:** both pilots - one after the other - select appropriate range for the AMM display; then they crosscheck airport layout, runway exit point, expected taxi route with redundant maps and charts or equivalent means (PF/PNF)).
- ✓ **Approach briefing:** identify runway exit point using the AMM (PF/PNF).
- ✓ **Rollout after landing**: switch EFIS/equivalent electronic flight instruments control panel on both sides to AMM display (PNF) if not switched automatically.
- ✓ **Taxiing in**: identical to taxiing out procedures described above.

3.10.7 Surface Movement Alerting (SMA)

Surface Movement Alert will provide alerts to flight crew in case of possible risk situations dealing with own ship runway incursion, usage of unsuitable taxiways, deviations from pre-defined routes and/or taxiway guidance/centre line, collision with fixed obstacles.

Note: Special attention must be drawn to the fact that modern 'mega transports' with considerable dimensions have their own onboard visual/electronic taxi aids, e.g. the AIRBUS A340-600 has installed a camera TV-system resulting in taxiing the aircraft on curved taxiways with the nose wheel extremely positioned off-centre in relation to the taxiway centreline. Therefore respective triggers for the sub-functions 'taxiway safety margins control' and 'taxi route conformance' must be type specific evaluated and validated in order not to infringe an onboard taxi aid and generating a contradictory alert.

From a pilot point of view in all high workload phases of flight careful attention shall be granted on reducing to safety alerts (neither general warnings nor information) when the aircraft is taxiing.

It is believed that the implementation of sub-functions 'taxiway safety margins control' and 'taxi route conformance' will be difficult due to frequent and short notice changes on the surface (e.g. NOTAMS like 'work in progress on taxiway XYZ: use caution'); it is anticipated that such warnings will prone to failure and nuisance; it must be kept in mind that each indication/alert/warning in the cockpit (valid, wrong or nuisance) requires attention and possible flight crew action thus distracting and possibly slowing down taxiing.

Especially any false, nuisance or spurious warning will greatly increase the workload on the flight deck thus leading to a slower taxi speed or stop of the aircraft until the relevance of such a warning can be assessed. Therefore an unacceptable high rate of false and /or nuisance warnings generated by the SMA will be a detriment to safety and efficiency of the whole system.

Any mature SMA system would be required to have the comparable performance in regard to safety as the today's used ACAS in the air: A consistent and highly reliable collision avoidance system on the ground on every airport would be a great benefit.

Because it is not known from simulation or flight trials how such a system would work in normal and not normal conditions the following procedure represents a general guideline how to cope with a SMA:

- CM 1 and 2 identify relevance and correctness of warning/alert ;
- CM 1 (normally taxiing the aircraft) stop the aircraft immediately if the situation is unclear ;
- CM 2 notifies ATC immediately if CM 1 has stopped the aircraft.
- CM 2 executes ECAM/EICAS action - or equivalent electronic means or checklists depending on aircraft design - as shown.

Note: ICAO DOC 9870 Manual for Preventing Runway Incursion, Appendix B, B1, [34] contains important procedural considerations which shall be taken into account when defining flight phase related procedures.

Departure Flights

- Normal Visibility Conditions:

The runway and taxiway alerting function - especially when the cleared taxi route can be up linked - will greatly benefit to traffic flow under high density conditions, e.g. a stream of aircraft taxiing for take off at peak hours.

- Low Visibility Conditions:

The SMA function will have an even more important influence on safety and efficiency compared to normal visibility conditions. Navigational errors, wrong or misinterpretation of taxi clearances communicated by voice, 'stand stills' because of unclear situations as interpreted by the flight crew will be reduced

Under LVP any nuisance warning /alert will undoubtedly lead to an intermediate stop of the aircraft.

Arrival Flights

- Normal Visibility Conditions:

Equivalent to a departure flight with the following addition: Depending of the time constraint, a 'leaving the runway and up-dated taxi clearance' will be up-linked and interpreted by the flight crew. Such a clearance should be available to the flight crew as early as possible (before reaching the proposed runway exit point) and should cover a predominant part of the route with reliability. Thus close and timely coordination of TWR and Apron service providers will be important to take full benefit of the Surface Management Function.

The sub-function 'fixed obstacle avoidance' has the potential to further enhance flight safety provided that the current airport layout with up-to-date modifications, e.g. derived from NOTAMS, is maintained in the relevant database.

- Low Visibility Conditions:

Equivalent to a departure flight (see above).

3.10.8 Braking and Steering Cues / Landing Operations[46]

The objective of Braking and Steering Cues function is to provide tactical support to the pilot manipulating the aircraft (normally CM 1), as a complement to other parts of the A-SMGCS that provide general surface situation awareness information for use by the assisting pilot (normally CM 2).

The support to the CM 1 during landing operations will be used to improve the reliability of runway occupancy times during the landing roll; it should assist the CM 1 in controlling aircraft deceleration in order to exit the runway as planned, or to warn him 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 Braking and Steering Cues 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. Consequently, the Braking and Steering Cues function should monitor the aircraft speed, aircraft heading, braking/steering effort and efficiency and give changes of advisories or confirmation for the landing roll. It should also determine if the designated runway exit can be used safely.

[46] AIRBUS has flight-tested a subfunction called Brake to Vacate. Assessment by dedicated airline pilots has shown that such a system would be a great benefit to safety and efficiency. At the present there is no procedural related information available.

During the approach briefing the flight crew will determine – depending on aircraft weight, met. conditions, runway status (e.g. dry, wet, contaminated) and local airport requirements at which exit the aircraft should clear the landing runway.

The PNF will enter respective values in the MCDU of the FMS and will activate the relevant subsystem.

PF confirms visually the accomplishments of actions done by the PNF and announces her/his agreement – if entries and settings have been checked as briefed.

During landing roll the PF and PNF monitor the deceleration performance of the auto-brake system, observe speed-control cues generated by the system.

In case of a non-normal operation of the system or if the system rejects clearing the runway at the intended exit together with or without relevant warnings generated by the flight warning computer software, the PNF will call-out when s/he detects such an irregularity.

PF confirms verbally that s/he is aware of the given callout(s), verifies the validity of such callout(s) and will take appropriate action to correct the landing deceleration or s/he will take another exit by clearly announcing his/her intention.

PNF will inform ATC if the proposed exit could not be made indicating at what exit the aircraft will be able to clear the landing runway by stating the appropriate designator.

3.10.9 Ground Traffic Display

ICAO A-SMGCS Manual (9830, §1.3.9) [25] refers to the importance of an onboard traffic information device:

'Surface guidance will include improved visual aids for automated guidance and control along the assigned route. However, 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.'

The Ground Traffic Display provides the flight crew with the surrounding traffic information (ground/airborne), i.e. what aircraft and vehicles that may come into conflict with each other. The traffic information is displayed on an appropriate display in the cockpit. The Ground Traffic Display is envisaged as a path to conflict avoidance alerting.

Departure Flights

The knowledge of actual traffic on the apron, manoeuvring area and runways will have considerable relevance to flight operations; up to now flight crews preparing for departure are listening on the ATC frequency in order to get a mental impression of traffic, especially when the outside view is limited; a much more accurate, relevant and consistent picture will be provided to individual cockpit crews by visually analysing the actual traffic at the airport.

- Normal Visibility Conditions:

CM 1 and CM 2 will crosscheck any conflict information obtained by voice communication, Ground Traffic Display function and/or own visual observation.

CM 1 and CM 2 will include the present traffic situation in their pre-departure briefing or equivalent.

- Low Visibility Conditions:

Limited vision to identify potential conflicts will be counterbalanced with the electronic picture: shadow objects and aircraft/vehicles will be then *'visible'*. The impact on safety and to some lesser extent to efficiency will be tremendous; conflict avoidance alerting is expected to be a further step.

- Relevant Operations:

Proposed procedures might be as follows:

✓ **On the gate / parking position:** CM 2 select transponder STBY ;

✓ **Before pushback, engine start or taxi:**

- CM 2 select transponder XPDR (and AUTO if available) ;
- CM 1 and 2 each for himself assesses traffic situation ;
- CM 1 make operational decision - if any ;
- CM 2 assesses traffic near/behind the aircraft as shown on the AMM and – when relevant -, callout such traffic.

✓ **Taxiing out:** Monitor the surrounding traffic as shown on the AMM (or on the equivalent display) and, if relevant, callout (CM 2). Especially the capability to monitor traffic behind the aircraft when pushing back is considered as particularly relevant from a pilot perspective.

Lining up:

- CM 2 resp. CM 1 select transponder TA/RA

Arrival Flights

- Normal Visibility Conditions:

It is assumed that the Ground Traffic display picture will be available in flight, i.e. during approach when the briefing for taxiing after landing takes place. With such service the flight crew will be able to better plan and coordinate the taxiing task.

- Low Visibility Conditions:

Equivalent to a departure flight (see above).

- Relevant Operations:

✓ **After landing:** when the runway is vacated, CM 2 select transponder XPDR (and AUTO if available) ;

✓ **Taxiing in**: CM 2 monitor the surrounding traffic as shown on the AMM (or the equivalent display) and – if relevant – callout such traffic;

✓ **At the gate / parking position**: CM 2 selects transponder STBY.

3.10.10 Traffic Conflict Detection Function

Similar to the use of ACAS when airborne, SOPs must be developed to address how to cope with warnings depicted on the Ground Traffic display and annunciated aurally.

Whenever the commander is not satisfied with such warning s/he will – regardless of any clearance received from ATC – take appropriate action.

CM 2 will announce any conflict warning/alert – verifying such warning with reference to the Ground Traffic Display.
CM 1 will acknowledge that s/he is aware of the call of his/her CM 2.
CM 1 will slow down or even stop the aircraft if s/he is not able to assess the situation by visual observation.
CM 1/CM 2 will assess the relevance and validity of such warning/alert.

CM 2 will immediately notify ATC with appropriate wording, e.g. 'conflict warning/alert.

3.10.11 TAXI-CPDLC

Preamble

With respect to data link ground operations two independent services are addressed with this section:

- Departure Clearance (DCL), in some areas of the world also called pre-departure clearance (PDC) when transmitted by ACARS via the respective Airline Operations Control Centre, which is requested by the flight crew and transmitted from the CDD when the respective aircraft is still on the stand/gate. Local procedures require a defined time frame within which such a request must be down linked, e.g. not more than 10 min before ready to taxi.
- TAXI-CPDLC which is requested by the flight crew for communication with the ATCO during manoeuvring on the aerodrome. If an expected taxi route has been up linked from the CDD already when the respective aircraft is still at the stand/gate, such route information would now be converted into a clearance.

The graphical presentation on a screen in the cockpit where to taxi, possibly on the AMM or an Electronic Flight Bag display, will ease the cockpit workload considerably; hold instructions clearly marked in dedicated colour coding will enhance safety thus decreasing the eminent potential of ground incidents and accidents.

For the beginning of TAXI-CPDLC however such graphical functionality will not be available thus text messages presented on the appropriate onboard data link unit will have to be interpreted by the flight crew and transformed in a mapping picture where to taxi.

A TAXI-CPDLC taxi route uplink is expected to avoid misunderstandings and, assembled with graphical tools, to provide assistance for the flight crew to guide the aircraft to taxi on manoeuvring areas:

- From the parking stand (gate) to the runway holding point before take-off, and
- From the runway to the stand (gate) after landing.

EASA has announced an NPA on this matter [3].

<u>**Present status on operational CPDLC trials in European airspace – on the ground and in the air**</u>

Flight crew tasks to obtain a DCL and a cleared taxi route (TAXI-CPDLC) are dependent on hardware and software installed in the cockpit. However current knowledge is based on:

1. life trials within the Link2000+ Programme [21]

2. airline experience and feedback participating in the Link2000+ initiative and operator derived procedures when using FANS 1/A CPDLC functions – which needed and have been granted an operational approval from the regulatory authority [1].

3. Flight crew related procedures for CPDLC use on the North Atlantic as provided by the respective ANSP, e.g. [47]

4. operational trials undergone in the EUROCONTROL CASCADE Programme [14], especially the output of D-TAXI trials at Brussels [15]

The following flight crew procedures have matured, are used in routine airline operations, have been evaluated and approved by the regulatory authority however they will need continuous updates during the EMMA2 project.

[47] NAV CANADA, Gander Data Link Oceanic Clearance Delivery, Crew Procedures, Version 17, 09/2006

Airlines wishing to introduce controller-pilot data link functionalities need to carefully consider the use of cockpit procedures and pilot roles in order to ensure that previously existing communication redundancy, i.e. when using voice, is not eroded away.

EUROCONTROL CASCADE Operational Focus Group has drafted message sets for use by ATCO and flight crews which are considered in this context – for details refer to D-TAXI OSED [15].

Operational experience out of the Link2000+ Programme led to following conclusions and recommendations for drafting flight crew procedures:

- The main difference in CPDLC versus voice procedures is the fact that an ATC clearance is not audible to both CM 1 and CM 2 simultaneously. Thus the CM 2 handling the CPDLC functions – mainly on the MCDU/DCDU – will have to call-out any incoming ATC message, even if a fault or erroneous message is received.

- It is therefore obvious that intra-cockpit communication will increase significantly; however in a high task-load environment in the cockpit the well known fact must be considered that intra-cockpit communication is weakening and leading to a possible shedding of secondary tasks thus being a detriment to flight safety. Adequate measures must be taken to mitigate the risk that the communication loop and the other cockpit loops would be separated.

- For all time critical issues on the ground voice communication will be utilized but can be accompanied by an automatic TAXI-CPDLC up link (cf. §3.7.3).

Taking these lessons-learnt issues into account the priority order of tasks for TAXI-CPDLC related procedures must clearly be observed by the flight crew:

1. Manipulate (on the ground) or fly (when airborne) the aircraft
2. Navigate horizontally and vertically
3. Communicate by keeping the internal and external communication loops alive

<u>**Departure Flights**</u>
The Clearance Delivery controller shall send the initial taxi route (if not up linked already automatically), which could be modified later on by the Ground controller;

Cockpit Preparation:
- CM 2 will check on the MCDU that a positive and confirmed logon with the appropriate ATCO unit is established (check LOGON STATUS or NOTIFICATION pages depending on installed hardware).
- CM 2 requests relevant D-ATIS, D-NOTAM, D-OTIS if available – if not up linked already automatically.

Before Start:

- CM 2 selects on his/her MCDU relevant COMM menu of the ATSU;
- CM 2 sends DCL request;
- CM 2 has to verbalise and assess received DCL content on the MCDU/DCDU;
- CM 1 confirms verbally his/her understanding of CM 2's announcement;
- CM 1 crosschecks the verbal announcement by his/her means, if s/he is satisfied with the content s/he will order CM 2 accordingly;
- CM 2 presses WILCO or UNABLE if such clearance is objected on command of CM 1;

- CM 2 leaves MCDU COMM menu of the ATSU selected - if not otherwise required.

Note 1: If both pilots need some time to analyse a DCL send a STANDBY message indicating to ATCO that the flight crew will respond later.

Note 2. For review purposes it might be required by the supervising authority granting operational approval that CM 2 initiates a printout of the valid DCL (reference is made to airline specific handling procedures of CPDLC clearances when airborne, ref. [1] which are part of the operational approval granted by the competent regulatory authority)

Before Taxi:

- CM 1/2 both will assess data link transmitted taxi route if such route has been up-linked earlier by the CDD and which at this stage is for information only, (it is not a valid ATC clearance):
  - if graphical presentation is available: by checking the content on each AMM or Electronic Flight Bag display
- When ready to taxi, CM 2 requests TAXI by data link to obtain a valid taxi clearance
- CM 2 reads back the clearance as presented on his/her MCDU/DCDU.
- In parallel, CM 2 press WILCO on command of CM 1 if s/he is in agreement on the content , if s/he is not in agreement press UNABLE and revert to voice communication.

Any deviations from the transmitted taxi clearance, i.e. a taxi clearance revision, will be exchanged between flight crews and the Ground controller either by voice, or by datalink, or both. If the use of data link for such revisions might be feasible is uncertain at the present time– see also chapter 3.7.3.

Arrival Flights

From a pilot perspective it is highly desirable that an initial proposal encompassing taxi route, the best suitable runway exit and final stand/gate would be made available onboard before the aircraft has started the final approach. However, as the pilot's choice of a runway exit should not be constrained, the system should be reactive enough to compute and propose for each possible runway exit an alternative (initial taxi route associated to runway exit).

Tentative associated procedure:

- When approaching an A-SMGCS equipped airport using TAXI-CPDLC functionality PF and PNF both will check on their respective MCDU COMM menu of the ATSU a positive and valid logon (LOGON STATUS or NOTIFICATION pages depending on installed hardware).
- The system might automatically transmit the arrival taxi route for information only approx. 20-10 min before landing (in alphanumeric on the MCDU/DCDU and in graphical format on the AMM or Electronic Flight Bag display).
- PNF press ROGER to indicate that the flight crew accepts the expected taxi route inbound
- After landing the flight crew will receive the inbound taxi route clearance by data link from the Ground controller. CM 2 will read the relevant text message from his/her MCDU/DCDU.
- CM 1 – normally manipulating the aircraft on the ground – confirms verbally his/her understanding of CM 2's announcement
- CM 2 performs an initial call to the Ground controller by voice as a back up and confirms the clearance (on the AMM/Electronic Flight Bag display -if available in graphical format- or by checking the text message on his/her MCDU/DCDU) by pressing the WILCO key on command of CM 1.

Normal and Low Visibility Operations:

Depending on time and geographical location of the respective aircraft on the runway when a TAXI-CPDLC clearance is received in the cockpit identical benefits to departure flights might be expected; it must be stressed that accurate clearance timing (e.g. when such clearance is transmitted) will have a great influence on flight crews' tasks:

- Both crew members are task loaded during landing and rollout until reaching adequate speed to leave the runway because of limited visual cues. As a consequence it is assumed that little or almost no capacity will be left to analyse and acknowledge such a clearance earlier than having reached taxiing speed.
- Transmitting a taxi information much earlier, i.e. when the remaining flight time is more than 20 minutes would be beneficial for a better task load distribution of the flight crew; however such early transmission from ATCO would probably be subject to frequent changes and thus being inadequate.

After landing[48]:

- CM 2 contact the ground controller by voice communication
- CM 2 will read the received text message from his/her MCDU/DCDU
- CM 1 – normally manipulating the aircraft on the ground – confirms verbally his/her understanding of CM 2's announcement
- CM 2 presses WILCO on command of CM 1
- CM 2 remains in contact with Ground control by voice communication in case time critical updates would be necessary.

Taxiing in:

- In case a valid clearance must be altered on the flight crews' side, a reject (UNABLE) and sending a new taxi request most probably will not be feasible due to the inherent time delay. Therefore CM 2 will request alternative routings by voice communication only.

Note: Such rejects are sometimes necessary as the respective airlines operational control centre might have advised the respected flight of changes in its gate/parking position which are not yet known by ATC. This suboptimal exchange of information might happen sometimes when the respective airline 'owns' a terminal or parts of it.

3.10.12 Ground / Air Database Upload

The function covers the update of the airport mapping data available in the aeronautical database on board as well as the NOTAMs not communicated to flight crews prior to flight and the ATIS information (D-ATIS). In addition, D-ATIS information can be enriched with METARs, NOTAMs, SNOWTAMs and PIREPs (D-OTIS service). Such service is provided by the respective airlines operations control centre today using ACARS.

The latest development on D-OTIS in the course of the CASCADE programme [14] will demonstrate that uploading information stored in the European Aeronautical Information Database (EAD) from the cockpit both on the ground and in flight can be accomplished already today.

As detailed research on the pilots expectations and filtering criteria should be undertaken (for instance through filtering of the messages before they reach the cockpit, in order to minimise the pilot effort as well as the usage of data link), setting up associated procedures is considered part of life data link trials.

[48] It might also be after having vacated the RWY, however in daily practice CM2 contacts Ground when feasible, preferably as soon as possible in order to avoid a stand still

Today's procedures when using ACARS on the ground are well developed and available. Similar procedures for use of D-OTIS which will include uploading of the relevant airport mapping data might be feasible.

During Cockpit Preparation

- CM 2 verifies that the onboard navigational data base cycle is valid on all systems
- CM 2 selects the COMMUNICATION function
- CM 2 sends INITIAL REQUEST – after having inserted required flight specific data
- CM 2 verifies uploaded data/messages and activates PRINT function
- CM 1 and 2 crosscheck successful upload of airport database

3.10.13 HUD Surface Guidance Symbology

Within the scope of the EMMA2 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 objective is to provide, using adapted symbology, tactical support to the CM 1 when on the ground, as a complement to other parts of the A-SMGCS that provide general surface situation awareness information for use by the CM 2 [49].

The HUD visually presents required symbology for flight and navigation on a partially reflective beam splitter and superimposed on real world image.

The use of HUD surface guidance symbology is envisaged in visibility condition 3 and 4, where the pilot cannot appreciate the instantaneous situation of the aircraft on the manoeuvring area. In such conditions it will be necessary to present on cockpit displays unambiguous information to allow the pilot to taxi the aircraft. It is intended to provide the pilot manipulating the aircraft on the ground (normally CM 1) with the following information:

Guidance cues to the CM 1 during taxi operations (for instance to help the pilot to anticipate commands for airplane movements, mainly in turn phase, steering cues for turn entry and exit information) if the visibility is reduced

How such a system is used on the ground is under development and evaluation. At present the following preliminary operating procedures will describe how the HUD/SGD might be utilized.

Taxiing out:

CM 1	follow SGD commands with reference to outside view
CM 2	monitor AMM by switching to the appropriate range, crosscheck aircraft position with reference to maps and charts or equivalent, keep a lookout as much as possible

Taxiing in:

CM 1	follow SGD commands with reference to outside view
CM 2	monitor AMM by switching from ND to AMM appropriate range (if not switched automatically), crosscheck aircraft position with reference to maps and charts or equivalent, keep a lookout as much as possible

CAUTION:
Experience from demonstrator tests as well as from flight reports using the HUD during approaches has revealed that CM 1 must not concentrate himself too much on the HUD/SGD commands neglecting outside cues of the real world.

[49] AIRBUS presently might offer a HUD as an option; BOEING will offer a fully developed HUD for both pilot positions on the B787 thus airlines will review their HUD policy based on the respective business case.

3.10.14 Automated Steering

Certification of such a function will be a major challenge; e.g. certification related to the airport moving map for autonomous taxiing would represent a costly initiative compared to its use some days in the year in reduced visibility conditions.

If and how such system will be developed and possibly be used on the ground is uncertain, thus setting up associated procedures is considered as immature.

3.11 A-SMGCS Operating Procedures for Vehicle Drivers

3.11.1 Preamble

According to ICAO document 9830 'Supplementary Requirements' (§2.6.12.1 and §2.6.12.2) [25]: Vehicle drivers, operating on the movement area, are recommended to be provided with services described in detail in chapter 2.3.

Provision of services for vehicle drivers operating on apron areas only, are not explicitly recommended by ICAO. Their provision of services is left to the responsible authority, which will establish them with the associated procedures and instructions.

Though most of the required services for vehicle drivers, operating on the movement area, may be performed through the availability and the use of ground visual aids (e.g. standard lighting, markings and signs), especially under good visibility conditions and on airports with clear runway/taxiway layout, EMMA 2 investigates on the development and implementation of new functions to support advanced services to vehicle drivers of respectively equipped vehicles under all visibility conditions.

Three successive steps (e.g. V1, V2, and V3) for the stepwise implementation of vehicle drivers' services, which require additional appropriate equipment and associated operating procedures, have been identified in the EMMA OSED document [5]. They start from a basic service to an advanced fleet management service and guidance by data in a high level A-SMGCS:

- **V1:** Airport Moving Map Function and Surface Movement Alerting Function
- **V2**: Ground Traffic Display Function
- **V3**: Vehicle Dispatch and Guidance by Data Link.

3.11.2 Airport Moving Map & Surface Movement Alerting

Providing vehicle drivers with an AMM function will:

- a) Help the vehicle driver to determine the actual position of his/her vehicle on the airport surface by displaying the own ship position with respect to aerodrome geographic location on a graphical display mounted in the vehicle cockpit.
- b) Supplement the out-of window visual reference to navigate on the airport movement area, thus increasing the situation awareness of the vehicle driver.

When the AMM allows the driver to mark areas (runways, taxiways, etc.) that have been restricted by ATC for a certain time and have been told by ATC to the vehicle driver, the driver shall mark this area as restricted at the AMM. The SMA function will alert the driver if s/he penetrates this area by means of a combination of audio and visual alerts. Particular attention should be paid to strictly reduce the number of false alarms.

All vehicles drivers who are subject to drive on the manoeuvring area should receive formal training and certification – in addition to specific driving qualifications, signage and markings - related to the equipment they will operate. In particular, rules, procedures and A-SMGCS aspects in all visibility conditions which would apply to vehicle drivers should be submitted to qualification.

The current operations, where ATCOs are responsible for operations on the runways and surface traffic on the manoeuvring area, will not be changed for the time being even through the introduction of the AMM and SMA. A vehicle driver, who is operating on the manoeuvring area, still has to request clearances and follow the instructions and clearances issued by the ATCOs.

The SMA function, which is based on AMM functionality/display, provides alerts and alarms to the vehicle driver in case of possible risk situations. This operational benefit is generally acknowledged, but as the SMA function for vehicle operation is still under development and it is unknown how it would work under real operational conditions, only general guidance how to cope with the alerts/alarms can be given.

Operating procedures for drivers using a vehicle equipped with AMM and SMA could be as follows:

- Checking procedures before driving: vehicle drivers shall switch on the equipment and check any failure; under conditions to determine, equipment failure might prevent the use of the vehicle; the identification of the driver should be possible through appropriate logon procedure. A possible way of detecting errors in the system could consist in:
    - Checking that the vehicle initial position and heading are correct.
    - Introduce/check information about restricted areas and fixed obstacles (this information could be given to the driver in paper before entering the car).
    - Verify that the restricted areas and fixed obstacles are correctly displayed.
    - Introduce destination point in the system.
    - Contact aerodrome control tower to obtain the route to follow.
    - Introduce the route into the system
    - Verify that the destination point and the designated route are correctly displayed.
- Configure the display according to user preferences, i.e. brightness, contrast, orientation, volume of sound alarms, etc
- Driving procedures:
    - Vehicle speed shall be adapted to cope with visibility conditions and react to alerts of the SMA. Vehicle speed might be recorded and controlled for post operations analysis.
    - Verify regularly that the route being followed is the correct one
    - In case of doubts about own location contact aerodrome control tower and ask for guidance.
- When an alert/alarm is generated:
    - React to the alert/alarm in due time, without delay
    - Identify relevance and correctness of warning
    - Estimate the associated risk of collision and take appropriate resolution action
    - Proceed as indicated by the alerting system (e.g. 'stop' or 'leave the runway')
    - If the situation is unclear contact the aerodrome control tower immediately.
    - Follow instructions of the aerodrome control tower
- Failure procedure:
    - Inform the aerodrome control tower immediately
    - Follow instructions of the aerodrome control tower

3.11.3 Ground Traffic Display

The Ground Traffic Display will receive, correlate and merge passive traffic surveillance data coming from different sources (ADS-B, TIS-B). Compared to the AMM and SMA the Ground Traffic Display (GTD) will provide the vehicle driver not only with information about his/her own position on the airport, or the location of fixed obstacles or restricted areas, but also with information about other traffic (aircraft and vehicles) on the apron and manoeuvring area, which gives the vehicle driver a more complete picture about the traffic situation and which will allow the vehicle driver to identify potential conflicts especially in VIS3 conditions. As far as the vehicle driver can rely on electronic information of potentially conflicting traffic in the vicinity of the vehicle, the lack of consistent visual information under VIS3 conditions can be compensated. The vehicle driver will be able to operate with a similar speed like under normal visibility conditions, which may have a positive influence on efficiency.

The current situation, where ATCOs are responsible for operations on the runways and surface traffic on the manoeuvring area, will be kept for the time being even through the introduction of the ground traffic display and the associated services. A vehicle driver, who is operating on the movement area of an airport, still has to request clearances and follow the instructions and clearances issued by the ATCOs. But as the ground traffic display can increase the vehicle drivers situational awareness in LVP and non-LVP conditions, the vehicle driver is supported to maintain visual spacing and avoid collisions, especially when crossing runways.

In addition to §3.11.2 operating procedures for drivers using a vehicle equipped with GTD could be as follows:

- Checking procedures before driving: vehicle drivers shall switch on the equipment and check any failure; under conditions to determine, equipment failure might prevent the use of the vehicle; the identification of the driver should be possible through appropriate logon procedure. A possible way of detecting errors in the system could consist in:
  - Verify that surrounding traffic is displayed at the right place and moving in the right direction.
- Driving procedures:
  - Check continuously the actual position of the vehicle by using the position information of the ground traffic display.
  - Maintain visual spacing between own vehicle and other aircraft/vehicles.
  - Verify regularly that there are not potential conflicts with surrounding traffic.
  - Avoid potential conflicts by appropriate actions.
  - Verify regularly that surrounding traffic is correctly displayed (at the right place and moving in the right direction).
  - Check that a runway is clear, before following an ATC clearance to cross runway.

3.11.4 Vehicle dispatch and guidance by data link

This service should support the vehicle driver by means of data link communications that can be used to transfer dispatch information and special guidance information on-board. Compared to today's procedures where voice communication is used to relay such information, this would lead to less ambiguity and a decrease of potential misunderstandings (no readback or hearback mistakes).

At present it is very often the case that vehicle drivers have two sets of voice communication radios in the vehicle – one station for the communication with the ATC tower and a second station for the communication with the own (airport) control centre. As far as both stations are working independently and on different frequencies the vehicle driver hears the communication on both frequencies at the same time. At times when s/he communicates with the airport control centre s/he is not able to listen to instructions from the ATC tower. This is a safety risk.

The replacement of the voice communication with the airport control centre by means of data link communication would solve this safety problem of simultaneous interaction. Data link is a very promising solution for the exchange of non time critical information, to unload the voice channel. As far as there are still some problems with guaranteed response times (of less than one second) data link is only partially used for delivery of instructions from the control tower to aircraft.

The communication between vehicle driver and airport control centre is less time critical, as far as the exchanged information is not used for control and positioning of the vehicle on the manoeuvring area, but is mainly dispatch information (gate numbers and commercial information about aircraft or other vehicles at the airport). It would be beneficial to relay this information by means of data link by the following reasons:

- Increased safety (vehicle driver can constantly listen to ATC tower frequency),
- Less ambiguity (dispatch information is available in a written form and can probably be printed in a similar way like in an aircraft cockpit environment),
- Response times and other technical characteristics are sufficient for use in communication between airport control centre and vehicle driver.

In addition to §3.11.2 and §3.11.3 following operating procedures for drivers using a vehicle equipped with Vehicle Dispatch and Guidance by data link could be as follows:

- Checking procedures before driving:
  - Send by data link request for destination point to airport control centre
  - Introduce/update/accept destination point and sent by data link a request for route to Aerodrome control tower.
  - Accept route received from aerodrome control tower sent by data link
  - Verify that the destination point and the designated route are correctly displayed.

4 Operational Requirements

4.1 General Principles

ICAO Doc 9830 Manual of A-SMGCS [25] is the main source used for the operational requirements listed in this chapter. Where these requirements conflict with other published requirements (e.g. EUROCAE, EUROCONTROL), the differences are noted. Where requirements do not exist from ICAO, other standard sources have been used or new requirements have been developed by the EMMA2 project.

With the EMMA2 structure of the operational requirements there are general and specific operational A-SMGCS requirements, whereas the specific requirements are related to the services of an A-SMGCS. They are listed under the respective sections below:

- General Requirements:
  - General A-SMGCS Requirements (GEN)
- Specific Requirements
  - Surveillance Requirements (SURV)
  - Conflict Prediction, Detection and Alerting (ALERT)
  - TAXI-CPDLC (TAXI-CPDLC)
  - Routing / Planning (ROUT)
  - Guidance (GUID)
  - Aircraft Onboard (AIR)
  - Vehicle Onboard (VEH)
  - Requirements related to A-SMGCS ATCO HMIs (HMI)

In addition, all operational requirements are subdivided into two sub-categories:

- Operational Service Requirements (Serv), which describe the A-SMGCS service
- Operational Performance Requirements (Perf), which define a performance limit that has to be achieved.

For instance, the second performance requirement of the surveillance service would get following acronym: SURV_Perf-02_Speed.

4.2 Assumptions

Cooperative Aircraft and Vehicles

At least in the manoeuvring area, all participating aircraft/vehicles should be cooperative in order to provide their identity and position to the A-SMGCS.

Transponder Operating Procedures

It is expected that flight crew comply consistently with the transponder operating procedures.

Source: [ICAO EANPG/48 [30]]

All requirements are ‘should’ statements. Where some source documents use ‘shall’ (or ‘must’, etc.) statements, these have been changed to ‘should’.[50]

All requirements refer to the A-SMGCS equipment and its use.

4.3 General A-SMGCS Requirements (GEN)

Service Requirements

GEN_Serv-01_Primary Functions

An A-SMGCS should support the following primary functions:

a) Surveillance
b) Routing
c) Guidance
d) Control

Source: [ICAO A-SMGCS [25]] 2.2.1

GEN_Serv-02_Planning Function

In order to achieve the maximum benefits of each level of A-SMGCS implementation, a supporting planning function should be included.

Source: [ICAO A-SMGCS] 2.2.2

GEN_Serv-03_Visibility Conditions

A-SMGCS should be capable of operating at a specified movement rate in visibility conditions down to AVOL. When visibility conditions are reduced to below AVOL, an A-SMGCS should provide for a reduction of surface movements of aircraft and vehicles to a level acceptable for the new situation.

Source: [ICAO A-SMGCS] 2.2.3

GEN_Serv-04_Provision of Information

The system should integrate movements to provide complete situational information to all users, and to provide conflict prediction and resolution for aircraft and vehicle movements.

Source: [ICAO A-SMGCS] 2.2.4

GEN_Serv-05_Modularity

A-SMGCS should be modular so that the appropriate level of service can be provided to different aerodromes as well as to different areas of an aerodrome.

Sources: [ICAO A-SMGCS] 2.2.5, ([EUROCAE-MASPS] 1.8.2 is similar)

Note: [EMMA2] Each aerodrome has its own operational needs and technological constraints. So each aerodrome will only implement the A-SMGCS modules fitting its needs and its technological choices in order to minimize the cost of its A-SMGCS. Consequently, A-SMGCS consists of many elements which, when integrated, are designed to meet the specific operational requirements of an aerodrome.

GEN_Serv-06_Users’ Responsibilities

Although the responsibilities and functions may vary, they should be clearly defined for all users of the system.

Source: [ICAO A-SMGCS] 2.3

[50] All [ICAO A-SMGCS] requirements are “should” statements.

GEN_Serv-07_Responsibility Assignment

An A-SMGCS should be designed so that the responsibilities and functions may be assigned to the following:

a) the automated system;
b) controllers;
c) pilots;
d) vehicle drivers;
e) marshallers;
f) emergency services;
g) airport authorities;
h) regulatory authorities; and
i) security services

Note: When A-SMGCS is in operation, pilots remain responsible for the safety and control of aircraft.

Source: [ICAO A-SMGCS] 2.3

Note 1: [EUROCONTROL] The allocation of functions and/or responsibilities might differ depending on visibility condition, level of automation and level of implementation of an A-SMGCS. A different division of functions among the control personnel (e.g. between authorities responsible for aerodrome movement control and apron management services) may also be necessary as a result of possible changes in procedures caused by automation.

Note 2: [EUROCONTROL] ATC will be responsible for the management and overall operation of the system. When certain functions will be delegated to automated elements of the system, responsibilities for the integrity and reliability of those functions lie with the service providers, certification authorities, manufacturers and software suppliers.

Note 3: [EUROCONTROL] ATC controllers and pilots are the only critical decision makers. Their decisions are based on surveillance data which have a specified integrity.

GEN_Serv-08_Modular Enhancement

The design principle of an A-SMGCS should permit modular enhancements.

Sources: [ICAO A-SMGCS] 2.4.1, ([EUROCAE-MASPS [13]] 1.8.2 is similar)

Note: [EMMA2] A-SMGCS will evolve from a SMGCS by progressive enhancements to match the desired level of operations. The competent authority will determine, in consultation with the users, whether existing SMGCS needs to be upgraded to A-SMGCS. A-SMGCS for each aerodrome will comprise a different mix of modular components dependent upon operational factors.

GEN_Serv-09_Equipment Status

The operational status of surveillance equipment should be monitored by the system, and alerts should be provided as appropriate.

Source: [ICAO A-SMGCS] 2.5.1.2

Note: [EMMA2]: For this requirement 'surveillance equipment' should be replaced by 'all A-SMGCS equipment'.

GEN_Serv-10_Design Concept

The A-SMGCS design concept should be built upon the integration of the fundamental and principal system elements and facilitate the upgrading of those elements whilst maintaining, where possible, the same HMI and references. This is important when considering harmonisation, familiarisation and training requirements, and will allow the evolution of the system design to a full A-SMGCS with the minimum negative impact on the users' ability to interface with the system.

Source: [EUROCAE-MASPS] 2.5.2

GEN_Serv-11_Aircraft Types 1

An A-SMGCS should support operations involving all aircraft types.

Source: [ICAO A-SMGCS] 2.6.2

GEN_Serv-12_Aircraft Types 2

An A-SMGCS should be capable of adaptation to cater for future aircraft types.

Source: [ICAO A-SMGCS] 2.6.2

Note: [EMMA2] Future 'aircraft types' have to be restricted to those 'aircraft types' that are already foreseeable to exist in the future.

GEN_Serv-13_Vehicle

An A-SMGCS should be capable of being used by appropriately equipped vehicles operating within the movement area.

Source: [ICAO A-SMGCS] 2.6.3

GEN_Serv-14_Susceptibility

The system should not be affected by:

a) Radio interference, including that produced by navigation, telecommunications and radar facilities (including airborne equipment);
b) Signal reflections and shadowing caused by aircraft, vehicles, buildings, snow banks or other raised obstacles (fixed or temporary) in or near the aerodrome environment; and
c) Meteorological conditions or any state of the aerodrome resulting from adverse weather in which operations would otherwise be possible.

Source: [ICAO A-SMGCS] 2.6.5

GEN_Serv-15_System Status

Equipment that shows control data should be both fail-safe and fail-soft.

Note: The term 'fail-safe' in this context means that sufficient redundancy is provided to carry data to the display equipment to permit some components of the equipment to fail without any resultant loss of data displayed.

The term 'fail-soft' means that the system is so designed that, even if equipment fails to the extent that loss of some data occurs, sufficient data remain on the display to enable the controller to continue operations.

Source: [ICAO A-SMGCS] 2.6.9.1

GEN_Serv-16_Failure Effect

In case of a failure of an element of an A-SMGCS, the failure effect should be such that the status is always in the 'safe' condition.

Source: [ICAO A-SMGCS] 2.6.9.2

Note: [EMMA2] For instance, the element should not provide wrong data that could impact on safety.

GEN_Serv-17_Failure Indication

All critical elements of the system should be provided with timely audio and visual indications of failure.

Source: [ICAO A-SMGCS] 2.6.9.3

GEN_Serv-18_Self-Restartable

An A-SMGCS should be self-restartable. The recovery time should be a few seconds.

Source: [ICAO A-SMGCS] 2.6.9.4,

Note: [EMMA2] ICAO gives no rationale for this requirement. It is unlikely that current equipment would meet this requirement. 'Few minutes' would be more realistic.

GEN_Serv-19_Restart

The restart of an A-SMGCS should include the restoration of pertinent information on actual traffic and system performance.

Source: [ICAO A-SMGCS] 2.6.9.4

GEN_Serv-20_Operational Change

An A-SMGCS should be capable of accommodating any change in the layout of the aerodrome (runways, taxiways and aprons).

Sources: [ICAO A-SMGCS] 2.6.10

Note: [EUROCONTROL] The A-SMGCS should also be capable of accommodating any change in procedures and operational rules at the aerodrome.

GEN_Serv-21_Interfaces

In order to fully benefit from an A-SMGCS by all parties concerned, the system should be capable of interfacing with the following:

a) air traffic management (ATM), including:
   1) arrival and departure management;
   2) arrival and departure coordination;
   3) optimized start-up sequence and times;
   4) optimized push-back sequence and times; and
   5) integrated initial flight plan processing system, central flow management unit, etc.;
b) aerodrome management systems;
c) existing and future ATS systems;
d) meteorological systems;
e) visual aids;
f) existing and future avionics;
g) aerodrome handling systems;
h) aircraft operators;
i) emergency authorities;
j) police/security authorities; and
k) other customers or users.

Source: [ICAO A-SMGCS] 2.6.16.1

GEN_Serv-22_User Interface

A-SMGCS should enable users to interface and function efficiently.

Source: [ICAO A-SMGCS] 2.6.16.3

GEN_Serv-23_Adaptation to Local Procedures

In order to efficiently assist the ATCO, the automated A-SMGCS services should be configurable to adapt to local ATC procedures and working methods.

Source: [EUROCONTROL D6 [20]], updated by EMMA2

GEN_Serv-24_Integrity

The system design should preclude failures that result in erroneous data for operationally significant time periods.

Sources: [ICAO A-SMGCS] 2.7.3.1, ([EUROCAE-MASPS] 3.1.1.1 is similar)

GEN_Serv-25_Data Validation

The system should have the ability to provide continuous validation of data and timely alerts to the user when the system must not be used for the intended operation.

Source: [ICAO A-SMGCS] 2.7.3.2

GEN _Serv-26_Availability

The availability of an A-SMGCS should be sufficient to support the safe, orderly and expeditious flow of traffic on the movement area of an aerodrome down to its AVOL.

Sources: [ICAO A-SMGCS] 2.7.4.1, ([EUROCAE-MASPS] 3.1.1.2 is similar)

GEN _Serv-27_Continuity of Service 1

An A-SMGCS should provide a continuous service.

Sources: [ICAO A-SMGCS] 2.7.4.2, ([EUROCAE-MASPS] 3.1.1.2 is similar)

GEN _Serv-28_Continuity of Service 2

Any unscheduled break in operations should be sufficiently short or rare as not to affect the safety of aircraft using the system.

Sources: [ICAO A-SMGCS] 2.7.4.2, ([EUROCAE-MASPS] 3.1.1.2 is similar)

GEN_Serv-29_Performance Monitoring

Monitoring of the performance of an A-SMGCS should be provided such that operationally significant failures are detected and remedial action is initiated to restore the service or provide a reduced level of service.

Source: [ICAO A-SMGCS] 2.7.4.3

GEN_Serv-30_Self-Checking System

An A-SMGCS should be designed with the appropriate level of redundancy and fault tolerance in accordance with the safety requirements. A self-checking system with failure alerts should be included in the system design.

Source: [ICAO A-SMGCS] 2.7.5.1

GEN _Serv-31_Reliability

A failure of equipment should not cause:

a) A reduction in safety (fail soft); and
b) The loss of basic functions.

Sources: [ICAO A-SMGCS] 2.7.5.2, ([EUROCAE-MASPS] 3.1.1 is similar)

GEN_Serv-32_Back-up

The system should allow for a reversion to adequate back-up procedures if failures in excess of the operationally significant period occur.

Source: [ICAO A-SMGCS] 2.7.5.3

GEN_Serv-33_System Failures

Operationally significant failures in the system should be clearly indicated to the control authority and any affected user.

Source: [ICAO A-SMGCS] 2.7.5.3

Performance Requirements

GEN_Perf-01_Speeds and Orientations

The system should be capable of supporting operations of aircraft and vehicles within the following parameters:

a) Minimum and maximum speeds for aircraft on final approach, missed approach and runways;
b) Minimum and maximum speeds for aircraft on taxiways;
c) Minimum and maximum speeds for vehicles; and
d) Any heading.

Source: [ICAO A-SMGCS] 2.6.4

GEN_Perf-02_Capacity

The A-SMGCS should be able to handle all aircraft and vehicles that are on the movement area at any time.

Source: [ICAO A-SMGCS] 4.1.1.5

Note 1: [EMMA2] Since capacity is a site-specific parameter, the determination of the maximum number of aircraft on the movement area should be based on the assumed peak traffic at the aerodrome. Aerodromes continually strive to increase capacity and therefore the number of movements, and hence aircraft and vehicles will probably increase over time. The A-SMGCS capacity figure should be sufficient to cater for expansion of this nature and reviewed on a regular basis to ensure that it is sufficient.

Note 2: [EMMA2] The A-SMGCS also needs sufficient capacity to handle obstacles on the movement area and traffic within the other areas of interest, e.g. aircraft on approach, helicopters, etc.

GEN_Perf-03_Velocity

The A-SMGCS should be able to accommodate the following speeds determined to within ± 2 km/h (1 kt):

a) 0 to 93 km/h (50 kt) for aircraft on straight taxiways;
b) 0 to 36 km/h (20 kt) for aircraft on taxiway curves;
c) 0 to 150 km/h (80 kt) for aircraft on runway exits;
d) 0 to 460 km/h (250 knots) for aircraft on final approach, missed approach and runways;
e) 0 to 150 km/h (80 kt) for vehicles on the movement area; and
f) 0 to 20 km/h (10 kt) for aircraft and vehicles on stands and stand taxi lanes.

Source: [ICAO A-SMGCS] 4.1.1.8

Note 1: [EMMA2] ICAO provides no rationale for the 1 kt accuracy requirement, which seems unnecessarily stringent and is not consistent with the surveillance position accuracy and update rate requirements. It may be useful for the pilot/driver to know own aircraft/vehicle speed with such accuracy, but for the controller it is not important.

[EUROCAE-MASPS] requires Reported Velocity Accuracy < 5m/s (10 kt), which is more realistic.

4.4 Surveillance Requirements (SURV)

Service Requirements

SURV_Serv-01_Surveillance Function 1

The surveillance function of an A-SMGCS should provide accurate position information on all movements within the movement area.

Source: [ICAO A-SMGCS] 2.5.1.1.a

Note: [EMMA2] 'Movement area' should be replaced by 'A-SMGCS coverage area', which includes the approach area.

SURV_Serv-02_Surveillance Function 2

The surveillance function of an A-SMGCS should provide identification and labelling of authorized movements.

Source: [ICAO A-SMGCS] 2.5.1.1.b

SURV_Serv-03_Surveillance Function 3

The surveillance function of an A-SMGCS should cope with moving and static aircraft and vehicles, within the coverage area of the surveillance function.

Source: [ICAO A-SMGCS] 2.5.1.1.c

SURV_Serv-04_Surveillance Function 4

The surveillance function of an A-SMGCS should be capable of updating data needed for the guidance and control requirements both in time and position along the route.

Source: [ICAO A-SMGCS] 2.5.1.1.d

Note: [EMMA2] 'Data to be updated' are not sufficiently identified by this requirement.

SURV_Serv-05_Operating Conditions

The surveillance function of an A-SMGCS should be unaffected by operationally significant effects such as adverse weather and topographical conditions.

Source: [ICAO A-SMGCS] 2.5.1.1.e

Note: [EMMA2] This is already covered by ICAO requirement §2.6.5.

SURV_Serv-06_Coverage 1

Within the required area of the aerodrome, surveillance should be provided up to an altitude so as to cover missed approaches and low-level helicopter operations.

Source: [ICAO A-SMGCS] 2.5.1.4

SURV_Serv-07_Coverage 2

Surveillance should be provided for aircraft on approach to each runway at such a distance that inbound aircraft can be integrated into an A-SMGCS operation so that aerodrome movements, including aircraft departures or aircraft crossing active runways, can be managed.

Source: [ICAO A-SMGCS] 2.5.1.5

SURV_Serv-08_Seamless Transition

A seamless transition should be provided between the surveillance for an A-SMGCS and the surveillance of traffic in the vicinity of an aerodrome.

Source: [ICAO A-SMGCS] 2.5.1.6

SURV_Serv-09_Detection of Obstacles

The A-SMGCS should detect obstacles, whether moving or stationary, located anywhere on the movement area of the aerodrome and having an equivalent radar cross section of 1 square metre or more.

Sources: [EMMA] based on [EUROCAE SMR-MOPS] 3.4.2, [ICAO SMGCS] annex F 4.2.1

Note 1: [EMMA2] An A-SMGCS is not designed to detect every kind of obstacle. The ATCO, as the main user of an A-SMGCS, is also not responsible for detecting obstacles. The airport authority is responsible for ensuring that the manoeuvring area is 'free of obstacles' [ICAO Annex 14 & Doc. 9476].

SURV_Serv-10_Airport Traffic Situation

The surveillance service should continuously provide the airport traffic situation, comprising:

a) Traffic information;
b) Traffic context.

Source: [EUROCONTROL D5 [19]]

SURV_Serv-11_Traffic Information 1

The surveillance service should continuously provide the following traffic information on the movement area, excluding passive and empty stands:

a) Position of all vehicles,
b) Identity of all cooperative vehicles,
c) Position of all aircraft,
d) Identity of all cooperative aircraft,
e) Position of all obstacles (cf. SURV_Serv-09_Detection of Obstacles)
f) History of the aircraft/vehicle positions (e. g. the 3 last positions displayed)

Note: The surveillance service should continuously provide the position and identity of all cooperative aircraft, including helicopters, within the entire coverage area.

Source: [EUROCONTROL D5], updated by EMMA2

SURV_Serv-12_Traffic Information 2

Other information about traffic is a local issue to be decided by the ATC Service provider, but should include at least the following information:

a) Vehicle type
b) Aircraft type
c) Aircraft gate
d) Departure runway

Source: [EUROCONTROL D5], updated by EMMA2

SURV_Serv-13_Manual Labelling

The surveillance service should provide to the user the ability to manually put the right call sign in the label associated to a vehicle equipped with co-operative equipment used for different vehicles.

Source: [EUROCONTROL D5]

Performance Requirements

SURV_Perf-01_Surveillance Reliability

In order to determine the reliability of the A-SMGCS surveillance function, the following parameters should be considered in the specification of surveillance equipment:

a) probability of detection (PD) - the probability that an aircraft, vehicle or object is detected and displayed;
b) probability of false detection (PFD) - the probability that anything other than an aircraft, vehicle or object is detected and displayed;
c) probability of identification (PID) - the probability that the correct identity of an aircraft, vehicle or object is displayed; and
d) probability of false identification (PFID) – the probability that the displayed identity of the aircraft, vehicle or object is not correct.

Source: [ICAO A-SMGCS] 3.4.1.4

Note: [EMMA2] In order to reasonably assess the reliability of an A-SMGCS surveillance service from an operational point of view, it is suggested to assess not only the overall probability of detection and identification of each movement but also the continuity of all aircraft and vehicle tracks over a longer period. 'Continuity' would be expressed by the number and lengths of detection or identification gaps related to the expected number of tracks.

SURV_Perf-02_Speed

The A-SMGCS should accommodate all aircraft and vehicle speeds that will be used within the coverage area with sufficient accuracy.

Sources: [ICAO A-SMGCS] 4.1.1.7

SURV_Perf-03_Reported Position Accuracy

The actual position of an aircraft, vehicle or obstacle on the surface should be determined within a radius of 7.5 m.

Sources: [ICAO A-SMGCS] 4.2.3

Note 1: [EUROCAE] The reported position accuracy should not exceed 7.5m on the manoeuvring area and 12m on the aprons (both at a confidence level of 95%).

Note 2: [EMMA2] The operational need for a specific accuracy may vary with different areas of interest (e.g. on runways, on taxiway, on stop bars). This is not specified by ICAO. It should be sufficient to meet the various needs of the users.

SURV_Perf-04_Altitude Accuracy

Where airborne traffic participates in the A-SMGCS, the level of an aircraft when airborne should be determined within ±10m.

Source: [ICAO A-SMGCS] 4.2.3

Note: [EMMA2] Justification has not been provided for the need of this accuracy of aircraft altitude for A-SMGCS. However, it has been decided to keep this requirement as such in the document because it is provided by ICAO. If no more information about this requirement is provided so far, the validation activity will determine the status of this requirement.

SURV_Perf-05_Update Rate

The position and identification data of aircraft and vehicles should be updated at least once per second.

Sources: [ICAO A-SMGCS] 4.2.4, ([EUROCAE-MASPS] 3.2.3 is similar for position data)

Note 1: [EUROCAE-MASPS] 3.2.3 and [ICAO-A-SMGCS] 4.2.4 require the update rate should be at least 1s. For example, in one second, an aircraft rolling at 10 knots covers a distance of approximately 5 metres. A vehicle at 35 km/h will move approximately 10 metres. In that case, the position displayed to the controller can differ by 10 metres from the actual position before being updated with the new reported value. If we take the maximum speed of 50 kts for aircraft on straight taxiways ([ICAO-A-SMGCS] 4.1.1.8), the displayed position can differ by 25 metres along the direction of motion.

Note 2: [EMMA2] With current technology, it is not possible to achieve an update rate of once per second for identification of stationary aircraft. This is because the on-board Mode S transponder automatically selects 'low squitter rate' (4.8s - 5.2s) when the aircraft is stationary on the ground. The use of multiple sensors will ensure an update rate of at least once per second for position data, but there is currently only one source for identification data (i.e. the aircraft's transponder).

4.5 Conflict Prediction, Detection and Alerting (ALERT)

ALERT_Serv-01_Conflict Detection 1

The control function of an A-SMGCS should detect conflicts and provide resolutions.

Source: [ICAO A-SMGCS] 2.5.4.1.c

Note: [EMMA2]: ATCOs do not want the A-SMGCS to provide resolution directly to aircraft and vehicles, but they would accept suggestions for possible resolutions.

ALERT_Serv-02_Conflict Detection 2

The control function of an A-SMGCS should provide alerts for incursions onto runways and activate protection devices (e.g. stop bars or alarms).

Source: [ICAO A-SMGCS] 2.5.4.1.e

ALERT_Serv-03_Conflict Detection 3

The control function of an A-SMGCS should provide alerts for incursions onto taxiways and activate protection devices (e.g. stop bars or alarms).

Source: [ICAO A-SMGCS] 2.5.4.1.f

ALERT_Serv-04_Conflict Detection 4

The control function of an A-SMGCS should provide alerts for incursions into critical and sensitive areas established for radio navigation aids.

Source: [ICAO A-SMGCS] 2.5.4.1.g

ALERT_Serv-05_Conflict Detection 5

The control function of an A-SMGCS should provide alerts for incursions into emergency areas.

Source: [ICAO A-SMGCS] 2.5.4.1.h

ALERT_Serv-06_Conflict Detection 7

With EMMA2 the conflict prediction, detection and alerting service should detect the conflicts/infringements provided in §3.4.

Source: [EMMA2 2-D1.1.1_SPOR]

ALERT_Serv-07_Short-Term Alerts

The following short-term alerts should be provided by the A-SMGCS within enough time to enable the appropriate remedial action:

a) short-term conflict alert: when the predicted spacing will be below preset/predefined minima;
b) area penetration alert: whereby an alert is triggered when a movement likely to enter a critical or restricted area is detected;
c) deviation alert: whereby an alert is triggered when the computed deviation will be more than the preset/predefined maximum deviation;
d) runway incursion alert: whereby an alert is triggered when a movement likely to enter an active runway (runway strip) is detected; and
e) taxiway (or an inactive runway being used as a taxiway) or apron incursion alert: whereby an alert is triggered when a movement likely to enter a taxiway or apron in use, which does not belong to its assigned route, is detected.

Source: [ICAO A-SMGCS] 2.5.4.3

Note 1: [EMMA2] Meeting these requirements is liable to result in an unacceptably high level of false or unwanted alerts. The use of 'entering' rather than 'likely to enter' would be more appropriate.

Note 2: [EMMA2] In b) and d) it is suggested to replace 'movement' by 'unauthorised movement'.

Note 3: [EMMA2] There are currently no separation minima defined by ICAO for surface movements.

ALERT_Serv-08_Medium-Term Alerts

Distinctive medium-term alerts should be provided well in advance to enable the appropriate remedial action to be taken with respect to:

a) Conflict prediction;
b) Conflict detection; and
c) Conflict resolution.

Source: [ICAO A-SMGCS] 2.5.4.4

Note 1: [EMMA2] Instead of short and medium term alerts, EMMA2 and EUROCONTROL are defining two stages of alert, which reflect the severity of conflicts.

ALERT_Serv-09_Alert Continuity

The information should be displayed continuously while the conflict is present.

Source: [ICAO A-SMGCS] 3.4.5.14

ALERT_Serv-10_Unambiguity

Conflict information should be unambiguously displayed on a surveillance display or by other appropriate means.

Source: [ICAO A-SMGCS] 3.4.5.14

ALERT_Serv-11_False Alerts

The number of false alerts should be sufficiently low to meet local safety objectives and to ensure that users do not, consciously or sub-consciously, downgrade the importance of alerts.

Source: [EUROCAE-MASPS] 3.3.2.3, paraphrased by EMMA2

ALERT_Serv-12_Runway Protection Area

The runway protection area should be composed of two boundaries: a ground boundary to detect the aircraft/vehicles on the surface, an air boundary to detect airborne aircraft.

Source: [EUROCONTROL D6]

ALERT_Serv-13_Ground Boundary

The length of the ground boundary should at least include the runway strip. The width should be defined differently according to the meteorological conditions.

Note 1: As an example based on today's 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 ground boundary will be used for both INFORMATION and ALARM stages.

Note2: In order to avoid unnecessary alerts to the controllers, it may be necessary to wait until the aircraft/vehicle has crossed the boundary.

Source: [EUROCONTROL D6]

ALERT_Serv-14_Air Boundary

The air boundary should be defined as a flight time to threshold and would take into account the two stages of alert, INFORMATION and ALARM, as well as the meteorological conditions:

- Non-LVP: INFORMATION around T1 = 30 seconds, ALARM around T2 = 15 seconds

- LVP: INFORMATION around T1 = 45 seconds, ALARM around T2 = 30 seconds

Note: These times should be configurable, depending upon optimisation at the aerodrome.

Source: [EUROCONTROL D6] based on [ICAO A-SMGCS] 3.4.5.12, 3.4.5.13

ALERT_Serv-15_Traffic Context Update

For the conflict/infringement detection, additional updated and correct traffic context information should be provided to the system such as:

- Airport configuration: runways in use, runways status, restricted areas

- Applied procedures and working methods: LVP, multiple line-up.

Source: [EUROCONTROL D6]

ALERT_Serv-16_Stages of Alert

The conflict prediction, detection and alerting service should provide 2 stages of alert:

Stage 1 alert is used to inform the controller that a situation which is potentially dangerous may occur that he/she needs to be made aware of. According to the situation, the controller receiving a Stage 1 alert may take a specific action to resolve the alert if needed. This is called the INFORMATION step.

Stage 2 alert is used to inform the controller that a critical situation is developing which needs immediate action. This is called the ALARM step.

Note: Controllers have different preferences, some of them want to be alerted only when the situation is critical (only Stage 2 alerts), and others wish more anticipation (2 stages of alert). This is confirmed by the evaluations performed in the BETA project. As a consequence, some ATS providers may choose to have ALARM only, and not use INFORMATION. The choice of having several stages of alerts presented to the controller, according to the conflict / infringement, should be left to the ATS providers.

Source: [EUROCONTROL D6]

ALERT_Serv-17_Alert Priority

Priorities should be established so as to ensure system logic performs efficiently. Conflict alerting priorities should be as follows:

a) Runway related conflicts.

b) Taxiway related conflicts

c) Apron related conflicts

Source: [ICAO A-SMGCS] 3.4.5.10

4.6 Conflict Resolution (RESOL)

RESOL_Serv-01_Conflict Resolution

Once a conflict has been detected, an A-SMGCS should either automatically resolve the conflict or, on request from the controller, provide the most suitable solution.

Source: [ICAO A-SMGCS] 2.5.4.5

Note: [EMMA2] It was rejected by the ATCOs in WG2 that a conflict situation would be solved automatically.

RESOL_Serv-02_Responsibility

The ATCO should remain the supreme authority to resolve a conflict situation.

Source: [EMMA2 SPOR] §2.1.2.1.2

RESOL_Serv-03_Traffic Information

A prerequisite for a reasonable and efficiently working automatic support is that the conflict resolution function is provided with at least all traffic information the ATCO is aware of.

Source: [EMMA2 SPOR] §2.1.2.1.2

4.7 TAXI-CPDLC (TAXI-CPDLC)

Service Requirements

TAXI-CPDLC_Serv-01_User Identification

In any data link dialogue, the end-user should be able to positively identify the other end-user.

Source: [ICAO DATALINK] *Part I,* 3.26

TAXI-CPDLC_Serv-02_Direct Voice Communication

In any data link based ATS, provision should always be made for direct pilot-controller voice communications.

Source: [ICAO DATALINK] *Part I,* 3.27

TAXI-CPDLC_Serv-03_Emergency Communication

The pilot or controller should be capable of initiating direct controller-pilot communication by voice in emergency or urgent, non-routine, safety-related situations.

Source: [ICAO DATALINK] *Part I,* 3.28

TAXI-CPDLC_Serv-04_User Interface

Simple actions should be used by either the pilot or controller to initiate voice communications.

Source: [ICAO DATALINK] *Part I,* 3.29

TAXI-CPDLC_Serv-05_Flight Information Distribution

Air traffic control facilities providing a data link based ATS should be capable of receiving, storing, processing, displaying and disseminating specific flight information relating to flights equipped for and operating within environments where a data link service is provided.

Source: [ICAO DATALINK] *Part I,* 3.32

TAXI-CPDLC_Serv-06_Human Machine Interface

Effective human-machine interfaces should exist on the ground and in the air to permit efficient interactivity between the pilot, controller and ground automation.

Source: [ICAO DATALINK] *Part I,* 3.34

TAXI-CPDLC_Serv-07_Transfer

The system should be capable of facilitating automatic transfer of data link authority within data link based ATS airspace using digital data interchange.

Source: [ICAO DATALINK] *Part I,* 3.37

TAXI-CPDLC_Serv-08_Contingency Procedures

In case of complete communications failure, procedures should be in accordance with ICAO provisions.

Source: [ICAO DATALINK] *Part I,* 3.38

TAXI-CPDLC_Serv-09_Service Termination Notification

In the event of an unexpected termination of a data link application, both the aircraft and the ground should be notified of the failure.

Source: [ICAO DATALINK] *Part I,* 3.39

TAXI-CPDLC_Serv-10_Message Emission

The CPDLC application requires:

a) That messages should be generated and sent in a time ordered sequence; and

b) That messages should be delivered in the order that they are sent.

Source: [ICAO DATALINK] *Part IV,* 2.1

TAXI-CPDLC_Serv-11_Message Recipient

The system should ensure that messages are sent to the specified recipient.

Source: [ICAO DATALINK] *Part IV,* 2.2

TAXI-CPDLC_Serv-12_Unsupported Service

When a ground system receives a message requesting an unsupported function or service, the ground system should respond indicating that the requested service is unsupported.

Source: [ICAO DATALINK] *Part IV,* 2.3

TAXI-CPDLC_Serv-13_Controller Interactions

The controller should be provided with the capability to respond to messages, including emergencies, to issue clearances, instructions and advisories, and to request and provide information, as appropriate.

Source: [PANS ATM Doc 4444] 14.1.2.1

Note:[EMMA2] The defined TAXI-CPDLC Service does not handle 'emergency' messages.

TAXI-CPDLC_Serv-14_Pilot Interactions

The pilot should be provided with the capability to respond to messages, to request clearances and information, to report information, and to declare or cancel an emergency.

Source: [PANS ATM Doc 4444] 14.1.2.2

Note: [EMMA2] The defined TAXI-CPDLC Service does not handle 'emergency' messages.

TAXI-CPDLC_Serv-15_Pilot and Controller Message Exchanges

The pilot and the controller should be provided with the capability to exchange messages which do not conform to defined formats (i.e. free text messages).

Source: [PANS ATM Doc 4444] 14.1.2.3

Note: [EMMA2] This requirement may not be feasible for A-SMGCS operations.

TAXI-CPDLC_Serv-16_Messages Management

Ground and airborne systems should allow for messages to be appropriately displayed, printed when required and stored in a manner that permits timely and convenient retrieval should such action be necessary.

Source: [PANS ATM Doc 4444] 14.1.2.4

TAXI-CPDLC_Serv-17_Aircraft Control

Aircraft should be under the control of only one ATC unit at a time, whether or not data link applications are being used.

Source: [ICAO DATALINK] *Part I,* 3.36

TAXI-CPDLC_Serv-18_Time Stamping

Time stamping should be available for all messages. The timestamp should consist of the date (YYMMDD) and time (HHMMSS). The timestamp should be the time the message is dispatched by the originating user.

Source: [ICAO DATALINK] *Part IV,* 2.7

TAXI-CPDLC_Serv-19_LACK

Each data link message transmission is followed by a logical (technical) acknowledgement (LACK), i.e. the sender gets an immediate feedback that the message has completely been transmitted and is available on the recipient's display.

Source: [EMMA2] *§3.7.3c*

Performance Requirements

TAXI-CPDLC_Perf-01_Time Accuracy

Wherever time is used in the CPDLC application, it should be accurate to within 1 second of UTC.

Source: [ICAO DATALINK] *Part IV,* 2.6

4.8 Routing / Planning (ROUT)

ROUT_Serv-01_Routing Function

Either manually or automatically, the routing function of an A-SMGCS should be able to designate a route for each aircraft or vehicle within the movement area.

Source: [ICAO A-SMGCS] 2.5.2.1.a

ROUT_Serv-02_Destination Change

Either manually or automatically, the routing function of an A-SMGCS should allow for a change of destination at any time.

Source: [ICAO A-SMGCS] 2.5.2.1.b

ROUT_Serv-03_Route Change

Either manually or automatically, the routing function of an A-SMGCS should allow for a change of route.

Source: [ICAO A-SMGCS] 2.5.2.1.c

ROUT_Serv-04_Routing Capability

The routing function of an A-SMGCS should be capable of meeting the needs of dense traffic at complex aerodromes.

Source: [ICAO A-SMGCS] 2.5.2.1.d

ROUT_Serv-05_Runway Exit

The routing function of an A-SMGCS should not constrain the pilot's choice of exit following the landing.

Source: [ICAO A-SMGCS] 2.5.2.1.e

ROUT_Serv-06_Manual Routing

In a manual routing mode, the routing function should be able to compute a **valid taxi route** between a given start point and a given end point taking into account local standard routes.

Source: [EMMA2 SPOR] §2.1.3.1.1

ROUT_Serv-07_Semi-Automatic Routing

In a semi-automatic mode, the routing function should also provide the control authority with advisory information on designated routes.

Source: [ICAO A-SMGCS] 2.5.2.2

Note: [EMMA2] 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.

ROUT_Serv-08_Automatic Routing

In an automatic mode, the routing function should also:

a) Assign routes; and
b) Provide adequate information to enable manual intervention in the event of a failure or at the discretion of the control authority

Source: [ICAO A-SMGCS] 2.5.2.3

Note: [EMMA2] 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; furthermore it should be guaranteed that the assignment of a taxi route is reasonable and reliable to best meet all current constraints and to minimise manual intervention by the ATCO. Therefore, the routing function needs all information the ATCO usually needs to generate a taxi route.

ROUT_Serv-09_Route Assignment 1

When assigning routes, an A-SMGCS should minimise taxi distances in accordance with the most efficient operational configuration.

Source: [ICAO A-SMGCS] 2.5.2.4.a

ROUT_Serv-10_Route Assignment 2

When assigning routes, an A-SMGCS should be interactive with the control function to minimise crossing conflicts.

Source: [ICAO A-SMGCS] 2.5.2.4.b

ROUT_Serv-11_Route Assignment 3

When assigning routes, an A-SMGCS should be responsive to operational changes (e.g. runway changes, routes closed for maintenance, and temporary hazards or obstacles.

Source: [ICAO A-SMGCS] 2.5.2.4.c

ROUT_Serv-12_Standard Terminology

When assigning routes, an A-SMGCS should use standardised terminology or symbology.

Source: [ICAO A-SMGCS] 2.5.2.4.d

ROUT_Serv-13_Route Availability

An A-SMGCS should be capable of providing routes as and when required by authorised users.

Source: [ICAO A-SMGCS] 2.5.2.4.e

ROUT_Serv-14_Route Validation

An A-SMGCS should provide a means of validating routes.

Source: [ICAO A-SMGCS] 2.5.2.4.f

ROUT_Serv-15_Provision of Routing Information 1

The routing function should be capable of providing routing information for aircraft and vehicles on the movement area and, where necessary, other areas used by vehicles.

Source: [ICAO A-SMGCS] 3.4.2.2

ROUT_Serv-16_Provision of Routing Information 2

The routing function should provide an optimised route for each participating aircraft and vehicle. It should consider the overall time for an aircraft or vehicle to complete the route in all visibility conditions.

Source: [ICAO A-SMGCS] 3.4.2.3

Note: [EMMA2] With an automatic routing function, 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, [EMMA2 SPOR] §2.1.3.1.3.

ROUT_Serv-17_Surface Traffic Flow Optimisation

The routing function should 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).

Source: [ICAO A-SMGCS] 3.4.2.4

ROUT_Serv-18_Intermediate Waypoints

The routing function should be able to handle predefined or user-defined intermediate waypoints (e.g. routing through de-icing stations).

Source: [ICAO A-SMGCS] 3.4.2.5

ROUT_Serv-19_Use of Alternative Routes

An alternative route should always be available on request.

Source: [ICAO A-SMGCS] 3.4.2.6

Note: [EMMA2] If the ATCO objects to the computed taxi route because of additional information/constraints that are not known to the routing function, the ATCO should be able to easily select an alternative route, [EMMA2 SPOR] §2.1.3.1.2.

ROUT_Serv-20_Route Modification / Cancellation

By human-initiated means, or as a result of a conflict, it should be possible to cancel or change an existing and used route. In the event that a route is cancelled, a new route to continue should be provided.

Source: [ICAO A-SMGCS] 3.4.2.7

Performance Requirements

ROUT_Perf-01_Routing Failure Rate

The requirements listed in the table below should be used in the design of the routing function.

Visibility conditions	Requirement (Failures per hour)
1	1.5E-03
2	1.5E-04
3	3.0E-06
4	1.5E-06

Source: [ICAO A-SMGCS] 4.3.1

Note 1: [EMMA2] ICAO gives no rationale for these figures, nor does it give the corresponding requirements for the other functions. Failure rate requirements will need to be estimated for each aerodrome.

Note 2: [EMMA2] A failure of the routing function may reduce efficiency of operations but it is unlikely that it would affect safety.

ROUT_Perf-02_ Processing Time

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 1s.

Source: [ICAO A-SMGCS] 4.3.2

ROUT_Perf-03_Timing and Distance Resolution

In the processing of optimised routes, the length of taxi distances should be computed to a resolution better than 10m, and timing to a resolution better than 1s.

Sources: [ICAO A-SMGCS] 4.3.3

Note: It is suggested to inform ICAO that there is no point in specifying resolution when no accuracy requirement is specified. Perhaps they mean accuracy, not resolution? If so, the requirement seems unnecessarily demanding.

4.9 Guidance (GUID)

Service Requirements

GUID_Serv-01_Guidance Function

The guidance function of an A-SMGCS should provide guidance necessary for any authorised movement and be available for all possible route selections.

Note: When visibility conditions permit a safe, orderly and expeditious flow of authorised movements, the guidance function will primarily be based on standardised ground visual aids. If expeditious flow is restricted due to reduced visibility, additional equipment or systems will be required to supplement visual aids in order to maintain flow rates.

Source: [ICAO A-SMGCS] 2.5.3.a

Note 1: [EMMA2] §3.4.3.4 [ICAO A-SMGCS] says: - Once a route has been assigned, the pilot or vehicle driver requires adequate information to follow that route. Guidance aids indicate where on the taxiway or apron the aircraft or vehicle can be manoeuvred safely. Switched centre line lights and/or addressable signs enable routes to be uniquely designated. With EMMA2 Ground guidance aids will not be implemented.

GUID_Serv-02_Indication to Pilots/Drivers

The guidance function of an A-SMGCS should provide clear indications to pilots and vehicle drivers to allow them to follow their assigned routes.

Source: [ICAO A-SMGCS] 2.5.3.b

Note: [EMMA2] When guidance information is transferred onboard, the flight crew and the vehicle drivers should be presented with information about the own position with respect to the airport layout, the restricted areas such as active runways, the destination and the taxi route to be followed.

GUID_Serv-03_Pilot/Driver Situational Awareness

The guidance function of an A-SMGCS should enable all pilots and vehicle drivers to maintain situational awareness of their positions on the assigned routes.

Source: [ICAO A-SMGCS] 2.5.3.c

GUID_Serv-04_Route Change

The guidance function of an A-SMGCS should be capable of accepting a change of route at any time.

Source: [ICAO A-SMGCS] 2.5.3.d

GUID_Serv-05_Restricted Areas

The guidance function of an A-SMGCS should be capable of indicating routes and areas that are either restricted or not available for use.

Source: [ICAO A-SMGCS] 2.5.3.e

Performance Requirements

GUID_Perf-01_Response Time

The overall response time of initiation of the guidance to verification that the correct route of information has been provided should not exceed 2 seconds.

Source: [ICAO A-SMGCS] 4.4.1

Note: [EMMA2] This requirement refers to the activation of taxiway guidance lights. The rationale is given in [ICAO A-SMGCS] 3.4.3.10.

GUID_Perf-02_Reversion Time

The reversion time should be a maximum of 0.5s.

Source: [ICAO A-SMGCS] 4.4.2

Note: [EMMA2] This requirement refers to the deactivation of taxiway guidance lights.

4.10 Aircraft Onboard (AIR)

Service Requirements

AIR_Serv-01_Pilot Considerations

Pilots should be provided with the following:

a) information on location and direction at all times;
b) continuous guidance and control during:
    1) the landing roll-out;
    2) taxiing to the parking position and from the parking position to the runway holding position;
    3) lining up for an appointed take-off position; and
    4) the take-off roll;
c) indication of the route to be followed, including changes in direction and indication of stops;
d) guidance in parking, docking and holding areas;
e) indication of spacing from preceding aircraft, including speed adjustments;
f) indication of spacing from all aircraft, vehicles and obstacles in visibility condition 4;
g) indication of the required sequencing;
h) information to prevent the effects of jet blast and propeller/rotor wash;
i) identification of areas to be avoided;
j) information to prevent collision with other aircraft, vehicles and known obstacles;
k) information on system failures affecting safety;
l) the location of active runways;
m) alert of incursions onto runways and taxiways; and
n) the extent of critical and sensitive areas.

Note: Most of the foregoing requirements may be satisfied by using ground visual aids.

Source: [ICAO A-SMGCS] 2.6.11

AIR_Serv-02_Airport Moving Map

The own ship position should be displayed to the flight crew 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.

Source: [EMMA2 SPOR]

AIR_Serv-03_Surface Movement Alerting

The flight crew should be presented with alerts in case of possible hazardous situations for the aircraft when manoeuvring on the airport surface, e.g. runway incursion avoidance, route deviation, etc.

Source: [EMMA2 SPOR]

AIR_Serv-04_Ground Traffic Display

The flight crew should be presented with surrounding movements of aircraft and controlled airport vehicles on aprons, taxiways, and runways.

Source: [EMMA2 SPOR]

AIR_Serv-05_Traffic Conflict Detection

The flight crew should be presented with information related to potential conflict(s) with other traffic on the airport surface.

Source: [EMMA2 SPOR]

AIR_Serv-06_Controller Pilot Data Link Communication

The flight crew should be supported by data link communications for the controller-pilot dialogues during ground movements (for arrival and departure phases) and the reception of routing information (e.g. standard taxi routes).

Source: [EMMA2 SPOR]

4.11 Vehicle Onboard (VEH)

Service Requirements

VEH_Serv-01_Driver Considerations 1

Vehicle drivers should be provided with the following:

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.

Source: [ICAO A-SMGCS] 2.6.12.1

VEH_Serv-02_Driver Considerations 2

In addition to the above, 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.

Note: Most of the foregoing requirements may be satisfied by using ground visual aids.

Source: [ICAO A-SMGCS] 2.6.12.2

VEH_Serv-03_Airport Moving Map

The vehicle position should be displayed to the vehicle driver 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.

Source: [EMMA2]

VEH_Serv-04_Surface Movement Alerting

The vehicle driver should be presented with alerts in case of possible hazardous situations for the vehicle when operating on the airport surface, e.g. runway incursion avoidance, route deviation, etc.

Source: [EMMA2]

VEH_Serv-05_Ground Traffic Display

The vehicle driver should be presented with surrounding movements of aircraft and controlled airport vehicles on aprons, taxiways, and runways.

Source: [EMMA2]

4.12 Requirements related to A-SMGCS ATCO HMIs (HMI)

Service Requirements

HMI_Serv-01_Interference

The operation of the A-SMGCS ATCO HMI should not interfere with other ATC responsibilities.

Source: [ICAO A-SMGCS] 2.6.15.1

HMI_Serv-02_Human/Machine Work Share

The A-SMGCS ATCO HMI should:

a) maintain a balance between human and machine functions;

b) permit the human to retain the power to make decisions as to those functions for which the human is responsible;

c) provide for a balanced mix of visual, audio and tactile inputs and responses.

Source: [ICAO A-SMGCS] 2.6.15.2

HMI_Serv-03_Efficient Input Devices

Input devices for the controllers should be functionally simple - involving the controllers in a minimum number of input actions.

Source: [ICAO A-SMGCS] 2.6.15.3

HMI_Serv-04_Ambient Light

It should be possible to view displays in all ambient light levels typical of an aerodrome control tower environment.

Sources: [ICAO A-SMGCS] 2.6.15.4, ([EUROCAE-MASPS] 2.5.3 is similar)

HMI_Serv-05_Onboard HMI 1

Account should be taken of the ability of the flight crew and vehicle drivers to respond to the guidance and control indications of the system.

Source: [ICAO A-SMGCS] 2.6.15.5

HMI_Serv-06_Onboard HMI 2

The system should provide pilots and vehicle drivers with essential routing, guidance and control data in a standardized form that at all times is conspicuous, legible, comprehensible and credible. Guidance should be implemented in such a way as to minimize the pilots'/ vehicle drivers' head down time, while maximizing the use of visual cues.

Source: [ICAO A-SMGCS] 2.6.15.6

HMI_Serv-07_Ease of Use

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.

Source: [ICAO A-SMGCS] 2.6.15.7

Note: [EMMA2] The A-SMGCS ATCO HMI should employ user friendly and familiar data entry means.

HMI_Serv-08_Harmonisation

The A-SMGCS ATCO HMI should be harmonised where possible with existing ATM HMI.

Note: ATM HMI may be specific to each local implementation.

Source: [EMMA2]

HMI_Serv-09_Adaptability

The HMI design should take into account the working environment of the user under various operational conditions. In this respect, the HMI should be adaptable to the various circumstances of the user. *Note: As an example, good visibility operations with high traffic throughput will require a different A-SMGCS set-up than that required for low visibility operations with reduced throughput.*

Source: [EMMA2]

HMI_Serv-10_Display Configuration 1

The HMI should allow the user to configure the display capabilities (e.g. range scale selection, pan/zoom, brightness, map overlays).

Source: [EMMA2]

HMI_Serv-11_Display Configuration 2

Where appropriate, it should be possible to configure the HMI according to local requirements.

Source: [EMMA2]

HMI_Serv-12_Traffic Situation Display

The HMI should display the complete airport traffic situation, allowing a rapid situation assessment.

Source: [EMMA2]

HMI_Serv-13_Target Selection

The notion of selection relates to the intention to interact with the traffic label and/or with the associated symbol and trajectory, and/or its representation through traffic data. The interface should support the notion of the currently selected traffic whose data the controller is currently examining or modifying.

The selection of an aircraft or vehicle should:

a) Highlight all the available representations of that traffic wherever such information appears, allowing for an easy location of the traffic information.
b) Show the surveillance label in the appropriate selected format.

Source: [EMMA2]

HMI_Serv-14_Indication of Responsibility

The controller should be provided with a clear indication that a movement is:

a) Entering her/his area of responsibility;
b) Being under her/his responsibility;
c) Leaving her/his area of responsibility.

Source: [EMMA2]

HMI_Serv-15_Accessible Traffic Information

Controllers should be presented with a clear 'picture' of the actual traffic situation in their areas of responsibility, and with all the necessary traffic data to assist them in their control and guidance tasks, i.e. to easily locate and identify aircraft and vehicles and to have a direct access to essential information.

Source: [EMMA2]

HMI_Serv-16_Traffic Data Sets

Different sets of traffic data should be provided in order to assist the controllers in different types of tasks (e.g. updating of data, planning of actions, traffic monitoring and conflict detection). These sets of data should be presented in a combination of graphical and textual formats.

Source: [EMMA2]

HMI_Serv-17_Graphical Traffic Information

Traffic position and trajectory should be provided in graphical format with labels to help the controller to easily locate each aircraft or vehicle and visualise its progress.

Source: [EMMA2]

HMI_Serv-18_Textual Information

Textual data should be provided in several formats:

a) Isolated sets of data related to each aircraft or vehicle, i.e. labels. Access to current flight parameters should be provided through interaction with any aircraft or vehicle label.
b) Lists of data allowing comparisons to help the controller to detect conflicts and to prioritise the planning of actions.
c) Electronic flight strips allowing the controllers to visualise the planned movements and to enter clearances.

Source: [EMMA2]

HMI_Serv-19_Indication of Unauthorised Traffic

The HMI should continuously indicate the position of unauthorised aircraft, vehicles and obstacles, whilst they are in the movement area, the runway strips and within any designated protected area as required by airport authorities.

Source: [ICAO A-SMGCS] 2.5.1.7

HMI_Serv-20_Update of Information

The traffic representation should be updated following:

a) Updates of the surveillance system
b) Controller or system initiated update of data.

Source: [EMMA2]

HMI_Serv-21_Minimal Screen Congestion

To avoid screen congestion and minimise overlap of displayed information, the permanently displayed traffic data should be only the minimum information needed by the controller.

Source: [EMMA2]

HMI_Serv-22_Presentation of Conflict Alerts 1

The controller should be provided with clear and visible indication of a conflict alert as soon as the alert exists. The provided information should include, at the minimum the identification of the involved aircraft and/or vehicle, wherever present.

Source: [EMMA2]

HMI_Serv-23_Presentation of Conflict Alerts 2

Conflict information should be unambiguously displayed on a traffic situation display or by other appropriate means.

Source: [EMMA2]

HMI_Serv-24_Presentation of Conflict Alerts 3

An alert should always be associated with a visual signal. The use of aural signal should be restricted to highly critical events requiring immediate action.

Source: [EMMA2]

HMI_Serv-25_Continuity of Alert

The HMI should continuously display a Conflict/Infringement alert while the conflict is detected.

Source: [ICAO A-SMGCS] 3.4.5.14

HMI_Serv-26_Alert Stages

An alert associated with a detected conflict should be provided with an adequate time and brought to the attention of the controller (**ALARM** coding). An alert associated with a predicted conflict (**INFORMATION** coding) should also be provided.

Source: [EMMA2]

HMI_Serv-27_Conflict Alert Priorities

Priorities should be established to ensure that system logic performs efficiently. Conflict alerting priorities should be as follows:

a) Runway incursions
b) Restricted area incursions

Source: [ICAO A-SMGCS] 3.4.5.10

HMI_Serv-28_Display of Lighting Status

The information about the status of the lighting system and protection devices such as stop bars (on/off) should be easily accessible to the controller.

Source: [EMMA2]

HMI_Serv-29_Indication of Route Deviation

The controller should be provided with clear and visible indication when a movement is deviating from its cleared route. The provided information should include, at the minimum, the identification of the involved aircraft, wherever present.

Source: [EMMA2]

HMI_Serv-30_Indication of Clearance Deviation

The controller should be provided with clear and visible indication when a movement is deviating from its clearance, or is operating without clearance.

Note: As an example, an aircraft not cleared to line up enters the runway, while an aircraft not cleared to land is on final approach.

Source: [EMMA2]

HMI_Serv-31_EFS display

The HMI should be capable of displaying electronic flight strips (EFS) to replace the use of paper strips and support the controller by reducing workload.

Source: [EMMA2]

HMI_Serv-32_EFS Content

The flight strips should contain data fields with all flight plan data relevant for the controller role at each position.

Source: [EMMA2]

HMI_Serv-33_EFS Display Layout

The presentation of electronic flight strips should be harmonised with current paper strips and the way they are stacked in flight strip bays.

Source: [EMMA2]

HMI_Serv-34_EFS Responsibility

The HMI at each working position should display the flight strips for flights under control of that position, as well as flights that will become controlled in the near future.

Source: [EMMA2]

HMI_Serv-35_EFS Grouping

Flight strips should be logically grouped in bays according to the phase of flight and user requirements (e.g. inbound, outbound, pending, etc.).

Source: [EMMA2]

HMI_Serv-36_EFS Sorting Criteria

The flight strip bays should contain lists of flight strips that are selected, sorted and presented according to configurable criteria.

Source: [EMMA2]

HMI_Serv-37_EFS Interaction

Controllers should have the capabilities to sort, move, and create new traffic data items in the traffic data lists.

Source: [EMMA2]

HMI_Serv-38_EFS Initialisation

Depending on the controller role, flight strips should appear in the entry (pending) area a pre-defined time before expected arrival or departure or when transferred from another control position.

Source: [EMMA2]

HMI_Serv-39_EFS Data Format

All traffic data items pertinent to a controller should be presented in clear and pre-defined formats that help to prioritise planning and control actions.

Source: [EMMA2]

HMI_Serv-40_EFS Configurability

Depending on operational needs, traffic data items should be highly configurable with regard to layout, size, shape, fonts, colours and interaction capability.

Source: [EMMA2]

HMI_Serv-41_EFS Extended Data Format

Traffic Data Items should be represented in minimum format or extended format based on controllers' choice. It should be possible to configure independently the extended format of traffic data items from the minimum format, by displaying and removing additional data.

Source: [EMMA2]

HMI_Serv-42_EFS Access to Additional Data

The controller should be able to expand the format of a displayed traffic data item to access additional data. By default, traffic data items should be presented under normal (minimum) format.

Source: [EMMA2]

HMI_Serv-43_EFS Timing of Arrival Traffic Data

Arrival traffic data should be displayed on concerned positions at a time parameter before the expected landing time (ELDT). The time parameter should be defined at local level.

Source: [EMMA2]

HMI_Serv-44_EFS Timing of Departure Traffic Data

Departure traffic data should be displayed on concerned positions at a time parameter before the expected off-block time (EOBT). The time parameter should be defined at local level.

Source: [EMMA2]

HMI_Serv-45_EFS Editing

If required locally, the controller should be provided with an easy and simple means to manually create a new flight plan or modify an existing flight plan.

Note: It may be necessary to create flight plans for towing operations and ground vehicle movements.

Source: [EMMA2]

HMI_Serv-46_EFS Handover 1

The HMI should provide a simple and secure means for handover of electronic flight strips between controllers.

Source: [EMMA2]

HMI_Serv-47_EFS Handover 2

The system should support the controller by automatic distribution/exchange of flight data and co-ordination between control positions.

Source: [EMMA2]

HMI_Serv-48_EFS Handover 3

Controllers should be provided with system assistance for transferring aircraft control from one to another control position.

Source: [EMMA2]

HMI_Serv-49_EFS Handover 4

The durability of annotations and instructions shall be ensured during handover.

Note [EMMA2] There shall be no loss of information on the flight strips (including any hand-written notes, etc.) when they are handed over from one controller working position to another.

Source: [EMMA2]

HMI_Serv-50_Transfer of Control Procedure

It should be possible to trigger the 'transfer of control' procedure either manually, e.g. by ATCO's input on a flight strip, or automatically, i.e. based on a significant flight event.

Source: [EMMA2]

HMI_Serv-51_Assumption of Control Procedure

Similarly, it should be possible to perform the 'assumption of control' manually or automatically depending upon local operational practices.

Source: [EMMA2]

HMI_Serv-52_Coordination Support

The introduction of automation of surface movement planning and electronic flight strips should support the ATCOs coordination between Ground and Tower controllers and adjacent Approach controllers.

Source: [EMMA2]

HMI_Serv-53_Ground Sectorisation

The ground sectorisation in a tower should be based on the following types of logical sectors:

a) Apron / Clearance Delivery,
b) Ground,
c) Tower

Source: [EMMA2]

HMI_Serv-54_Combined Roles

It should be possible to combine the operational roles in a number (1 to n) of physical controller working positions based on operational constraints, e.g. traffic load, time of day, etc.

Source: [EMMA2]

HMI_Serv-55_Clearance Input

Controllers should be presented with a means to input clearances into the system (via the electronic flight strip and/or labels).

Source: [EMMA2]

HMI_Serv-56_Clearance Types

Clearances should represent the normal set of clearances a controller gives to an aircraft, such as: 'cleared to land', 'continue approach', 'go-around', 'vacate', 'cross', taxi', 'start-up', 'push-back', 'hold', 'line-up', 'conditional line-up', 'take-off', 'abort take-off', etc.

Source: [EMMA2]

HMI_Serv-57_Clearance Durability

The durability of the clearances input shall be ensured until the next clearance has been input.

Note [EMMA2]: As an example, there should be a clearance button which the controller presses when the clearance is given. The text on the button automatically changes to the next logical clearance in the sequence. In most cases, the strip will also be automatically transferred to another strip bay area on the controller's screen or to another control position; in any case, the clearance given is no longer shown on the e-strip. It is recorded, however, and it is possible for the controller to take back a clearance by use of the "regress" button.

Source: [EMMA2]

HMI_Serv-58_Correction of Mistakes

It should be possible for the controller to easily correct a mistaken action.

Source: [EMMA2]

HMI_Serv-59_Route Assignment

The HMI should be able to show and to assign the most probable/standard route to individual aircraft and vehicles to provide safe, expeditious, efficient and free conflict movement from its current position to its intended position.

Source: [EMMA2]

HMI_Serv-60_Route Presentation

The route (path) information should be indicated alphanumerically within the EFS but should also be linked with the traffic situation display (TSD) (on request of the ATCO the route could be presented graphically).

Source: [EMMA2 SPOR] §2.1.3.1.3

HMI_Serv-61_Route Modification

The controller should be provided with a quick and efficient means to modify a system assigned route to an aircraft.

Source: [EMMA2]

HMI_Serv-62_Route Manual Intervention

The ATCO can always intervene with the electronic flight strips to set additional constraints unknown to the routing function.

Source: [EMMA2 SPOR] §2.1.3.1.3

HMI_Serv-63_Minimum Weather Information

Minimum weather information should always be displayed and available to the controller and should include (per runway): surface wind direction (touch down) and strength (graphical and text), QNH (mb), ATIS code, temperature and dew point.

Source: [EMMA2]

HMI_Serv-64_Additional Weather Information

The controller should be provided with an easy means to access to additional weather information that should include surface wind (Touch Down and Stop End), visibility, current weather, cloud ceiling, QNH and QFE (mb and inches), weather forecast information, RVR conditions and a remarks section. The display should either be provided on controller request or automatically triggered on specific events defined at local level.

Source: [EMMA2]

HMI_Serv-65_NAVAIDS Status Indication

The controller should be provided with an easy means to display on request the status of airport NAVAIDS equipment.

Source: [EMMA2]

HMI_Serv-66_NAVAIDS Serviceability

The controller should be warned automatically in case of modification of airport NAVAIDS equipment serviceability.

Source: [EMMA2]

HMI_Serv-67_Stop Bars Integration

The display of stop bars should be integrated into the A-SMGCS HMI.

Source: [EMMA2]

HMI_Serv-68_Stop Bars Status

The current status of stop bars should always be presented to the controller.

Source: [EMMA2]

HMI_Serv-69_Automatic Switching of Stop Bars

Switching (i.e. activate or de-activate) status of stop bars should be changed automatically according to ATCO clearances and a/c position.

Source: [EMMA2]

HMI_Serv-70_Manual Switching of Stop Bars

It should also be possible to manually switch (i.e. activate or de-activate) protection devices such as stop bars.

Source: [EMMA2]

HMI_Serv-71_Datalink Equipment

The controller should be informed if an aircraft is datalink equipped or not.

Source: [EMMA2]

HMI_Serv-72_Datalink Dialogue Failure

An alert should be presented to the controller when a datalink dialogue has failed.

Source: [EMMA2]

HMI_Serv-73_Datalink Dialogue De-activation

The controller should have the means to de-activate the datalink dialogue for a particular aircraft.

Source: [EMMA2]

Performance Requirements

HMI_Perf-01_Map Accuracy

The accuracy of all map information presented on the traffic situation displays should be sufficient to ensure that each movement is seen in the correct position with respect to the aerodrome layout and other traffic, and particularly with respect to hold lines and stop bars.

Source: [EMMA2]

HMI_Perf-02_Display Resolution

The resolution of the HMI displays should be sufficient to not noticeably degrade the accuracy of the information being presented.

Source: [EUROCAE-MASPS] 3.4.1.1

HMI_Perf-03_Position Registration Accuracy

The accuracy with which the HMI registers position information on the display should be sufficient to not appreciably degrade the accuracy of the information it receives from surveillance.

Source: [EUROCAE-MASPS] 3.4.1.2

HMI_Perf-04_Display Latency

The presentation of surveillance data to controllers should not be delayed to an extent where it is no longer operationally acceptable. A worst-case value of 500ms is appropriate.

Note: For [ICAO A-SMGCS], the latency and validation of position data for aircraft and vehicles should not exceed one second.

Source: [EUROCAE-MASPS] 3.4.1.3, ([ICAO A-SMGCS] 4.2.5)

HMI_Perf-05_Response Time

The response time of the ATCO HMI should be adequate to allow the controller to make inputs without having to wait unduly for the system to process and validate the input. This should be less than 250ms on average and should never exceed 500 ms.

Note: Where external systems are being activated by input at the ATCO HMI, the response time does not include the time taken for the external system to respond. In such cases, the controller should be given an immediate acknowledgement that a message has been sent and a further acknowledgement once the reply has been received from the external system.

Source: [EUROCAE-MASPS] 3.4.1.5

5 Annex I

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