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Implementation Roadmap for A-SMGCS

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Executive summary

The roadmap for A-SMGCS implementation covers the definition by the EMMA2 project partners of the successive steps and their associated timeframes leading-up to the complete deployment of the A-SMGCS services to Air Traffic Controllers, Flight Crews and Vehicle Drivers targeted by the project.

The roadmap is built using as basis the EMMA2 "2-SP12-D1.1.1 A-SMGCS Services, Procedures, and Operational Requirements (SPOR)" , it takes into account the EUROCONTROL A-SMGCS Levels 1 and 2 (current situation) and the long-term target for airport operations defined by the SESAR programme (2020 horizon).

The roadmap has been established by considering:

- Deployment of service steps (increments)
- A set of qualitative decision criteria used for rating the services individually
- Availability of technological enablers and dependencies between automated systems
- One generic airport case and a set of key airport characteristics influencing A-SMGCS implementation.

The roadmap represents a consolidated view of the operational availability of the EMMA2 services at ECAC airports in line with the SESAR Master Plan for European ATM.

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1 Introduction

1.1 Purpose

The roadmap for A-SMGCS implementation covers the definition by the EMMA2 project partners of the successive steps and their associated timeframes leading up to the complete deployment of the A-SMGCS services to Air Traffic Controllers, Flight Crews and Vehicle Drivers targeted by the project.

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The results presented in this document are in accordance with the EMMA2 DoW and consist in the:

- Definition of the aspects and viewpoints to be covered by the Implementation Roadmap;
- Consolidated Implementation Roadmap reflecting EMMA2 partner views;

1.2 Scope

The scope of the document is:

- the identification and assessment of implementation aspects for A-SMGCS
    - The assessment has been conducted using qualitative or quantitative results from EMMA2 test airports but also considering an implementation of A-SMGCS services on a generic European airport
- the description of the roadmap for the implementation of A-SMGCS services.

The terms A-SMGCS, implementation, and roadmap need to be further introduced and explained and/or scoped:

For *A-SMGCS* the following is considered:

- The higher levels of A-SMGCS as identified by the ICAO Manual and analysed in the EMMA2 SPOR represent the target to be reached from operational perspective that is decomposed in surveillance, control, routing / planning and guidance services;

For *implementation*, the following is considered:

- Implementation is related to the implementation of A-SMGCS services per users, i.e. ATC Controllers, Flight Crews and Vehicle Drivers, as described in the EMMA2 SPOR document.

- The overall A-SMGCS implementation is decomposed into ***implementation steps*** for each service and per user with the objective to group services and technical enablers in order to establish successive implementation steps (incremental) that are assessed against the following **criteria**:
    - Development status of the technical enabler
    - Degree of interrelations to other functions (complexity)
    - Quality of the enabling equipment (needed reliability)
    - Impact on current operational procedures (maturity of the changes)
    - Cost considerations
    - Airport Throughput improvements
    - Safety improvements

A baseline for the definition of ***implementation steps*** has been provided in the EMMA Air-Ground Operational Service and Environmental Description (OSED [5])
The EMMA Implementation Steps defined in OSED is already an initial implementation roadmap. Implementation Steps are being reconsidered in this document to elaborate a more precise plan in respect to *what will be available when.*

The development of the roadmap has been carried out in parallel to the EMMA2 validation activities involving the same partners. At the time of publication of the roadmap, the deliverable 2-D.6.7.1 had not been finalised, however, the partners had taken in to account the results to date of the EMMA2 validation activities during the development of this document.

For the *Roadmap* time scale, the following is being considered in accordance to SESAR implementation definition as defined in the document D4 “The ATM Deployment Sequence” (cf. Reference 8):

- Short-Term up to 2013;
- Medium Term from 2013 to 2020;
- Long Term 2020 and afterwards

1.3 Structure of the document

The structure of the document is as follows:

- Section 1: Introduction
- Section 2: Aspects and Approach for the Implementation Roadmap
- Section 3: Implementation of the Services to ATCOs
- Section 4: Implementation of the Services to Flight Crews
- Section 5: Definition of A-SMGCS Services Roadmap
- Section 6: Conclusions
- Section 7: Annex I

1.4 Acronyms

Abbreviation	Full term
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance Broadcast
AIP	Aeronautical Information Publication
ALDT	Actual Landing Time
AMAN	Arrival Manager
AMM	Airport Moving Map
ANSP	Air Navigation Service Provider
ANT	Airspace & Navigation Team
APN	Apron Control
APW	Area Proximity Warning
A-SMGCS	Advanced Surface Movement Guidance and Control System
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
ATS	Air Traffic Services
ATSU	Air Traffic Service Unit
BETA	operational Benefit Evaluation by Testing an A-SMGCS
CDD	Clearance Delivery Dispatcher
CDM	Collaborative Decision Making
CPDLC	Controller Pilot Data Link Communication
CTOT	Calculated Take Off Time (CFMU)
DCDU	Data Link Control And Display Unit
DCL	Departure Clearance
DMAN	Departure Manager
DOTIS	Datalink Operations Terminal Information
ECAM	Electronic Centralized Aircraft Monitoring
EFIS	Electronic Flight Instrument System
EFS	Electronic Flight Stripes
EICAS	Electronic Indicating And Crew Alerting System
ELDT	Estimated Landed Time
EMMA	European airport Movement Management by A-SMGCS
EOBT	Estimated Off-Block Time
ETOT	Estimated Take Off Time
FDPS	Flight Data Processing System

FMS	Flight Management System
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LOC	Line of Change
LVP	Low Visibility Procedures
MCDU	Multifunctional Control and Display Unit
MET	Meteorological
MLS	Microwave Landing System
MLT	Multilateration
MSAW	Minimum Safe Altitude Warning
ORD	Operational Requirements Document
OSED	Operational Services and Environment Description
PF	Pilot Flying
PNF	Pilot Non-Flying
PSR	Primary Surveillance Radar
R/T	Radio telephony
RIMS	Runway Incursion Monitoring System
RVR	Runway Visual Range
RWY	Runway
SGS	Surface Guidance Symbology
SMGCS	Surface Movement Guidance and Control Systems
SMR	Surface Movement Radar
SPOR	A-SMGCS Services, Procedures, and Operational Requirements
SSR	Secondary Surveillance Radar
STCA	Short Time Conflict Alert
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
TRD	Technical Requirements Document
TSAT	Target Start Approval Time
TWR	Aerodrome Control Tower
TWY	Taxiway
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
XPDR	Transponder (Mode S)

2 Aspects and Approach for the Implementation Roadmap

The section explains the approach selected for the definition of the incremental steps towards the full implementation of A-SMGCS services considering the potential options for European airports.

2.1 Phased Implementation of A-SMGCS Services

The term IMPLEMENTATION in the document refers to the E-OCVM Phase V5 defined as follows:
Implementation – this is the phase when products and procedures are combined to create an operational system at a specific site.

The roadmap proposes a stepped implementation of A-SMGCS services along 3 main time periods:

- **Short Term**: Implementation prior to 2013
- **Medium Term: Implementation between 2013 and 2020**
- **Long Term: Implementation from 2020 onwards**

Note: The proposed phases correspond to the proposed implementation packages (IPs) by the SESAR D4 Master Plan and such correspondence is further explained in 5.4.

2.1.1 Integrated 'suite' of A-SMGCS services

The implementation of A-SMGCS services either on the ground, on-board aircraft or on vehicles requires to address carefully the integration issues, either from an operational or a technical perspective:

- **Operational viewpoint:**
  - Transition from A-SMGCS level 2 services to include what is provided to ATCOs and the Flight Crew and to build the additional services on top of the legacy systems.
  - The implementation of other systems supporting airport operations but not dedicated to surface movements such as CDM for instance shall be also considered to ensure that consistent views on future airport systems are drawn.
- **Legacy operational procedures and systems viewpoint:** the impact of proposed evolutions from existing procedures and systems for ATCOs or current Flight Crew procedure shall be assessed.
- **Deployment viewpoint:** several proposed new A-SMGCS services require the creation of additional interfaces between existing systems and/or the use of air-ground data link communications.

  From a deployment perspective, this means that A-SMGCS services shall not only be considered on an individual basis but rather as a 'suite' of applications that are made available by the progressive implementation of new system interfaces or air-ground data link communication services.

2.1.2 Key Decision Criteria

In order to build the roadmap for the implementation of A-SMGCS services at a Pan-European level, several key decision criteria need to be defined and used to trace decisions made for the deployment sequence.

The roadmap for the implementation of future A-SMGCS services has been developed by considering the following key decision criteria as follows:

- **Operational benefits and constraints**: 2 main types of operational benefits are identified for A-SMGCS services
  - Safety benefits: through the timely detection of hazardous situations on the airport surface
  - (Airport) Throughput benefits: through the maintenance of optimum airport throughput in all visibility conditions and the enhanced predictability and planning of surface movements

  The main constraints from an operational perspective are identified through the impact of new services on the current operational procedures.

- **Availability and maturity of individual technical enablers**: the roadmap shall consider for the required technical enablers their respective level of maturity (technologies), the size of the changes to existing applications/equipments as well as the required timescale for aircraft equipage (e.g. avionics lifecycle).
- **Complexity of deployment**: the dependencies between the technical enablers to realise the targeted end-user services need to be clearly identified in order to determine coherent implementation steps allowing a progressive and incremental implementation of A-SMGCS. The available plans and policies for the development or deployment of the underlying technologies in ATM, such as SESAR System Capability Levels for the 2007-2020+ time horizon, shall be used ensure the coherence of the A-SMGCS roadmap with other implementation targets.
- **Costs**: available cost figures shall be used to relate the proposed implementation steps to the 'size' of the targeted benefits. Such criteria shall also be looked at from the perspective of the airport 'characteristics' such traffic level, layout complexity or the frequency of low visibility conditions.

2.2 Generic Airport

The deployment of A-SMGCS at European airports primarily concerns a set of 30 to 40 airports, each having specificities with respect to surface movements (e.g. aerodrome layout complexity).

With the aim of identifying a representative case and a set of associated 'middle-of-the-road' recommendations (to avoid addressing local specificities only) a generic airport representative of the European major airports is used for the implementation of EMMA2 services.

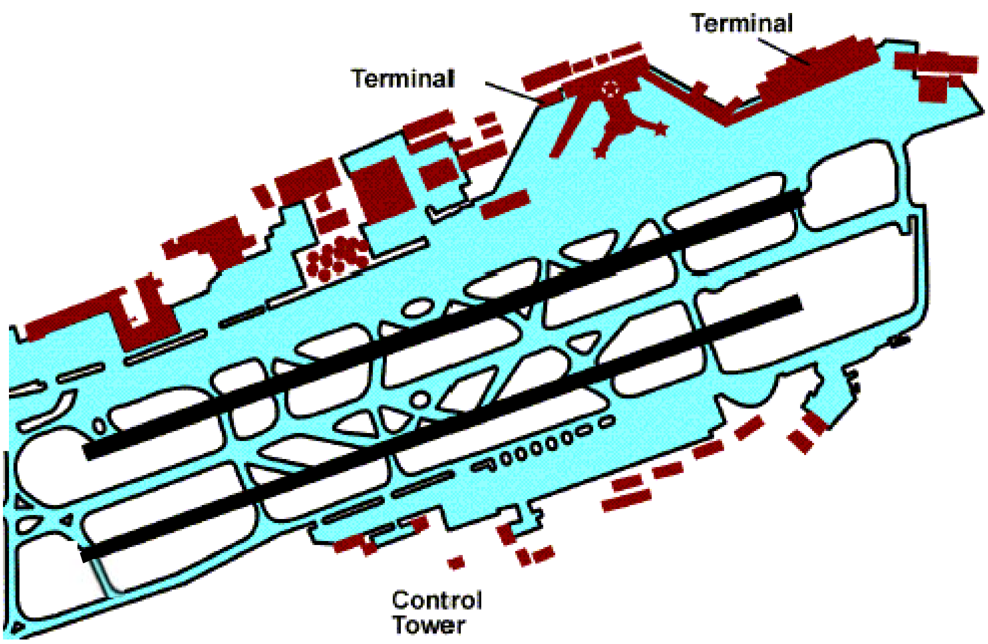

Figure 1: Layout Example for Generic airport

In the context of the A-SMGCS Implementation Roadmap, it is proposed to define several characteristics of such generic airport as follows:

- Traffic Level: around 600 movements / day in average (total 200 000 movements / year)
- Aerodrome layout: minimum 2 runways, low complexity of taxiway/runway organisation (not runway safety hotspots)

- Number of low visibility days: average of 5 days (cumulative operational time) per year

It shall be noted that the major European airports can be related to such generic case (main differences identifiable) and have implemented or are currently implementing A-SMGCS surveillance plus other services. However, at present small airports have not implemented A-SMGCS services due to cost v.s. benefits considerations.

2.3 'Score Card' for A-SMGCS services steps

In order to trade-off the different options for A-SMGCS services implementation it is proposed to perform the rating of individual service steps using the following 'score card':

Rating ⇨ **Criteria List** ⇩	**Generic Airport**	
	Description	**Rating**
Operational Improvements	Relates to the size of the gains provided for surface movement operations	
Airport Throughput	e.g. increase of runway or taxiway throughput (when traffic demand exists)	Low / Medium / High
Efficiency of Surface Movements	e.g. reduction of runway occupancy time, reduction of taxi and waiting time	Low / Medium / High
Safety Benefits	e.g. reduction in runway incursions	Low / Medium / High
Operational Constraints	Relates to the constraints imposed to ATCOs, Flight Crews	
Impact on current procedures or practices		Low / Medium / High
Technical Enablers		
Complexity of technical enablers	Complexity of technical developments to be made to existing or new (e.g. level of reliability required)	Low / Medium / High
Availability of technical enablers	Readiness for operational use of automated systems	Prior to 2013 / 2013 – 2020 / 2020+
Dependencies to other A-SMGCS services or existing airports or on-board systems		No rating, dependencies impact the timeframe for implementation
Cost Considerations		Low / Medium / High Medium: acquisition costs comparable to a surface movement radar (typically 1.5MEUR) for ground systems or to a Mode-S transponder for aircraft systems (typically 50kEUR per aircraft).

Table 1: 'Score card' for EMMA2 services

3 Implementation of the Services to ATCOs

The services for ATCOs, which correspond to the four A-SMGCS main functions (surveillance, control, routing, and guidance) have been decomposed into a series of implementation steps during the EMMA project. The description of the services summarised below is extracted from the EMMA2 SPOR document ([1]).

3.1 Surveillance Service

The Surveillance service addresses the detection, identification and positioning of aircraft and vehicles on the airport areas.
The service is decomposed in steps relating to the coverage of airport areas by ground surveillance system and then with the exploiting of alternative technologies for the identification and positioning of movements at the airport and its vicinity.

3.1.1 Step 1: Surveillance of Manoeuvring Area for Aircraft and Vehicles

3.1.1.1 Description

The first surveillance service step provides position, identification and state vector (heading, speed) of aircraft and vehicles in the manoeuvring area to ATCOs.

3.1.1.2 Operational Improvements

- Safety benefits: contributes to the improvement of controller's situational awareness in particular to prevent runway incursions
- Airport throughput: supports the optimum use of taxiways and runways in all visibility conditions (night, rain, fog but not for VIS COND 3 and 4)
- Efficiency of surface movements: optimizes the density and distribution of aircraft on the airport surface and reduces the ATCOs workload to maintain a proper situation awareness, particularly in dense traffic situation and with impaired visibility

3.1.1.3 Operational Constraints

- ATC procedures
  - There's no particular influence on current procedures except that the ATCO can neglect the flight crews' position reports since the ATCO can rely on the position reports provided by the A-SMGCS traffic situation display

- Onboard procedures
  - The main operational constraint relates to the transponder management procedure which is a Flight Crew responsibility.

3.1.1.4 Technical Enablers Availability and Complexity

The main technical enablers are identified as follows:

- Provision of traffic information (identity, position, state vector): available today (except for ADS-Out)
  - Cooperative sensors (Multi-lateration, ADS-B and SSR)
  - Non-cooperative sensors (SMR, PSR, and others that meets the A-SMGCS operational requirements as defined in the EMMA2 SPOR and EMMA ORD documents)
  - Vehicle equipment (Transmitter and receiver)
- Provision of traffic context information: available today (digital airport chart)
- Human-machine interface: available today

3.1.1.5 Ground Prerequisite for the implementation of Step 1 of the Surveillance service

None

3.1.1.6 Aircraft Prerequisite for the implementation of Step 1 of the Surveillance service

- Mode-S Transponder

3.1.2 Step 2: Step 1 + Surveillance of Aircraft on Apron Areas

3.1.2.1 Description

The step 2 provides the same functions as Step 1 to ATCOs but in addition the position, identification and state vector of aircraft are provided on the APRON area.

3.1.2.2 Operational Improvements

- Efficiency of surface movements: optimises the density and distribution of aircraft on the apron surface and reduces the ATCOs/ Apron Managers workload to maintain a proper situation awareness, particularly in dense traffic situation and with impaired visibility

3.1.2.3 Operational Constraints

No particular influence on existing procedures

3.1.2.4 Technical Enablers Availability and Complexity

Same as Step 1. The coverage of apron areas requires additional surveillances sensors (gap fillers), the complexity of these areas and proximity with buildings may induce significant costs to achieve the desired coverage.

3.1.2.5 Ground Prerequisite for the implementation of Step 2 of the Surveillance service

None

3.1.2.6 Aircraft Prerequisite for the implementation of Step 2 of the Surveillance service

- Mode-S Transponder

3.1.3 Step 3: Step 2 + Surveillance of Vehicles on Apron Areas

3.1.3.1 Description

The step 3 provides the same service to ATCOs or Apron Managers compared to step 2 but in addition the position, identification and state vector of vehicles are provided on the APRON area.

3.1.3.2 Operational Improvements

- Efficiency of vehicle operations : enables the real-time monitoring of vehicle movements on the ground handlers or apron controllers

3.1.3.3 Operational Constraints

There are no operational constraints since the management of the vehicle equipment does not involve the driver.

3.1.3.4 Technical Enablers Availability and Complexity

Technical enablers are similar to step 2. The main difference for vehicle tracking is that low-cost technologies can be used since airworthiness is not required. .

3.1.3.5 Ground Prerequisite for the implementation of Step 3 of the Surveillance service

None

3.1.3.6 Aircraft Prerequisite for the implementation of Step 3 of the Surveillance service

There are no additional dependencies to aircraft equipment compared to step 1 and step 2.

3.1.4 Step 4: Surveillance using alternative technologies (e.g. ADS-B)

3.1.4.1 Description

The fourth surveillance service step provides the position, identification and state vector of aircraft (and/or vehicles) on the manoeuvring and APRON area to ATCOs through the use of alternatives surveillance technologies, including dependent surveillance provided by ADS-B.

3.1.4.2 Operational Improvements

The use of ADS-B aims at providing the same operational improvements to airports not equipped with traditional independent surveillance means (PSR) or cooperative surveillance means (Mode S multi-lateration).

3.1.4.3 Operational Constraints

The use of ADS-B implies that the integrity of the traffic situation picture presented to ATCO is not handled by a single equipment but by each aircraft individually.

3.1.4.4 Technical Enablers Availability and Complexity

Compared to Mode-S multilateration there is an increased complexity relating to the equipage of all aircraft with an appropriate means for position and state vector acquisition on the airport surface with the required level of service.

3.1.4.5 Ground Prerequisite for the implementation of Step 4 of the Surveillance service

None.

3.1.4.6 Aircraft Prerequisite for the implementation of Step 4 of the Surveillance service

This step is strongly related to the certification and implementation of the avionic equipment which is providing the quality and reliability of position and state vector data.

3.1.5 Rating of Service Steps

3.1.5.1 Generic Airport

The following table depicts the evaluation of the implementation service steps for the Surveillance service.

		Step 1	Step 2	Step 3	Step 4
	Generic Airport	**Manoeuvring Area (aircraft and vehicles)**	**Step 1 + Apron Area for aircraft**	**Step 2 + Apron area for vehicles**	**Manoeuvring + Apron using altern. technologies (ADS-B)**
Operational Improvements					
Airport Throughput	Low/Medium/High	Medium	Medium	Medium	Medium
Efficiency surface movements	Low/Medium/High	Medium	Medium	Medium	Medium
Safety Benefits	Low/Medium/High	High	Medium	Medium	Medium
Operational Constraints					
Impact on current ATC procedures or practices	Low/Medium/High	Low	Low	No	Low
Impact on on-board procedures		XPDR procedure	XPDR procedure	XPDR procedure	ADS-B procedure
Technical Enablers					
Complexity	Low/Medium/high	Medium for Mode S Mlat High for ADS-B-out	same as Step 1	same as Step 1	High for ADS-B out
Availability of Technologies	Available - 20XX				
Provide Traffic Information		today (except ADS-B-out)	today (except ADS-B-out)	today	2010+
Provide Traffic Context		today	today	today	today
Interface with user		today	today	today	today
Dependencies to other A-SMGCS services		None	None	None	None
Dependencies to aircraft equipment		XPDR	XPDR	None	ADS-B-out for surface movements
Costs	Low/Medium/high Medium: comparable to SMR or Mode-S XPDR	High	High	High	High for on-board equip. (ADS-B-out for surface movement) But reduced cost for airport (MLAT as back-up)
IMPLEMENTATION PHASE	prior to 2013, prior to 2020, 2020 onwards	today	today	today	2020+ (delay required for full equipage)

Figure 2: Rating of Surveillance Service Steps

3.1.5.2 Influence of Airport Characteristics

The section addresses the potential variations (compared to generic airport) for the size of operational improvements or the timeframe for the implementation of service steps.

3.1.5.2.1 Traffic Level

Most large European airports and several medium airports have already implemented Steps 1 and 2. The maintenance of optimal airport throughput in reduced visibility conditions (e.g. VIS COND 2) is a major driver for their implementation.
The major operational benefits will be more evident as the traffic load increase.

3.1.5.2.2 Airport Layout Complexity

Airports with runway safety hotspots (complex organisation of taxiways in the vicinity of runways) benefit largely from surveillance step 1 (enhances visual observation).
Surveillance step 2 benefits also to the management of complex aprons and is implemented together with Step1.
Nevertheless the size and layout of the airport influence the complexity of the technical enablers as more multi-lateration sensors may be required. As consequence the time schedule could be affected.

3.1.5.2.3 Number of LOW VIS days

Validation results show that the service improves the ATCO situational awareness in reduced visibility conditions. Therefore it has to be implemented with priority at airports confronted with a high number of LOW VIS days.

3.2 Control Service

The control service addresses the support to ATCOs for the maintenance of traffic separation, the issue and distribution of clearances and instructions to Flight Crews and vehicle Drivers, the planning of surface movements as well as the support for the transfer of control responsibility between ATCOs.

3.2.1 Step 1: Conflict Detection and Alerting (Surveillance-based alerting)

3.2.1.1 Description

The step consists in the detection and alerting for conflicts (risk of collision) between aircraft and vehicles as well as in infringements into restricted areas, runways and taxiways by either aircraft or vehicles. The detection of runway and taxiway conflicts (potential loss of separation) is made on the basis of information provided by the surveillance service and using pre-defined rules for the trigger of timely alerts to ATCOs.

3.2.1.2 Operational Improvements

High benefits in terms of safety are expected to be provided in the airport operations by the introduction of runway and taxiway conflict detection and alerting service.
The main operational improvement concerns the prevention of ground collisions between aircraft or with airport vehicles by an earlier ATCO's awareness of critical traffic situations (cf. Reference 7).

3.2.1.3 Operational Constraints

No change to operational procedures and practices (safety net). No increase of ATCO's workload is expected.
Experience gained at already equipped airports confirms that to be effective, the implementation of such safety net shall guarantee a low level of false and unwanted alerts.

3.2.1.4 Technical Enablers Availability and Complexity

Other enablers required are:

- Conflict prediction, detection and alerting system/algorithm: available today
- HMI: reuse of surveillance HMI operationally used today

3.2.1.5 Ground Prerequisite for the implementation of Step 1 of the Control service

- Surveillance service (at least step 1)

3.2.1.6 Aircraft Prerequisite for the implementation of Step 1 of the Control service

- None: non-cooperative aircraft (transponder failure) or non-equipped vehicles are tracked by the using the independent non-cooperative surveillance technique (PSR)

3.2.2 Step 2: Conflict Prediction and Alerting (traffic and clearance conformance monitoring)

3.2.2.1 Description

- "Conformance monitoring" service monitors the behaviour of the movements to check if they do what they are supposed to do. The service 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…
- "Conflicting clearances detection" service performs a cross-check of the set of clearances provided at the same time on an airport in order to ensure their consistency. Example: a crossing clearance is issued at the same time a take off clearance is given for the same runway…
- Transfer/assumption of control in general means transfer/assumption of responsibility, information, and communication. In a conventional A-SMGCS the paper strip is passed between ATCOs, and the Flight Crew is prompted to contact the next position on the respective frequency via voice- communications. 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.

3.2.2.2 Operational Improvements

Control Step 2 services are expected to provide the following operational improvements:

- High safety benefits: the service enables the detection of precursors of conflicts and thus provides an increased reaction time for ATCOs and Flight Crews (anticipation)
- Medium benefits on efficiency of surface movements: the service enables the detection of non-conformance to taxi movements allowing the ATCO to take corrective actions to maintain the efficiency of surface movements.

3.2.2.3 Operational Constraints

To be effective and generate correct alerts, the system needs to be updated by the controller. Clearances delivered by voices must be associated to controller input in the system, e.g. via electronic flight strip. Appropriate HMI design and controller training will have to be associated with the implementation of this step to mitigate the constraint.

3.2.2.4 Technical Enablers Availability and Complexity

- Control Step 1 technical enablers (refer to section 3.2.1.4)
- Electronic Flight Strips including processing of ATCO clearances: available today
- Flight Data Management ensuring data synchronisation among adjacent sectors/positions: available today
- Conformance monitoring algorithms/systems: prior to 2013

3.2.2.5 Ground Prerequisite for the implementation of Step 2 of the Control service

- Surveillance service (step 1)
- Routing (step 2 semi automatic or step 3 automatic) for detecting non conformance to taxi routing clearance

3.2.2.6 Aircraft Prerequisite for the implementation of Step 2 of the Control service

None.

3.2.3 Step 3: TAXI-CPDLC

3.2.3.1 Description

TAXI-CPDLC service allows the ATCO to provide the flight crew with ground specific information messages and to issues ground clearances via data-link instead of using voice. Since TAXI-CPDLC is used to upload the taxi route on-board of the aircraft (graphical depiction on the airport moving map), this service may also be classified as a Guidance Service.

3.2.3.2 Operational Improvements

TAXI-CPDLC service is expected to provide:

- Medium operational improvements on efficiency of surface movements: the use of data link instead of voice for the provision of non-time-critical or non-safety-critical information to Flight crews reduces the occurrences of R/T frequency congestion but does not decrease the workload of ATCOs
- Low safety benefits:
  - in avoiding possible misunderstanding in voice communications between ATCO and Flight crews
  - the provision by data link of taxi route and clearances onboard in a textual or/and graphical form reduces the amount of taxi route deviations

3.2.3.3 Operational Constraints

As the introduction of TAXI-CPDLC service will significantly change the way ATCOs communicate with the flight crews, an impact on current procedures and practices is expected.
At least in the beginning of its implementation, the use of data link in a mixed mode environment (i.e. data link + voice communications) (mix of equipped and non-equipped aircraft and a mix of data link and voice clearances) is expected to have a high impact on ATCO workload. This impact of this transition can be mitigated by the design of operational procedures supported by adapted HMI.

3.2.3.4 Technical Enablers Availability and Complexity

- Electronic Flight Strips including processes of clearances: available today
- Point to point data link to enable TAXI-CPDLC: 2013-2020
- HMI: under development

3.2.3.5 Ground Prerequisite for the implementation of Step 3 of the Control service

- Routing

3.2.3.6 Aircraft Prerequisite for the implementation of Step 3 of the Control service

The implementation of the service depends on the availability of CPDLC on board of the aircraft, such a system exists today for en-route operations but requires addition developments to meet Flight Crews requirements for surface movement (graphical interface).

3.2.4 Step 4: Conflict Resolution (proposal of a conflict solution)

This step proposes automated advice to the controller for conflict resolution. Additional research deserves to be carried out for examination and validation.

3.2.5 Step 5: Conflict Resolution (automated resolution)

This last step of the Control service proposes automated conflict resolution. Similarly to step 4, additional research deserves to be carried out for examination and validation.

3.2.6 Rating of Service Steps

3.2.6.1 Generic Airport

The following table depicts the evaluation of the implementation service steps for the Control service.

	Generic Airport	Step 1 **RWY Conflict Detection and Alerting (surveillance based monitoring)**	Step 1 Extension **TWY Conflict Detection and Alerting (surveillance based monitoring)**	Step 2 **Conflict Prediction and Alerting (traffic and clearance conformance monitoring)**	Step 3 **TAXI-CPDLC**	Step 4 **Conflict resolution (proposal of the solution)** NOT MATURE	Step 5 **Conflict resolution (resolution)** NOT MATURE
Operational Improvements							
Airport Throughput Benefits	Low/Medium/High	Low	Low	Low	Low		
Efficiency surface movements	Low/Medium/High	None	Low	Medium	Medium		
Safety Benefits	Low/Medium/High	High	High	High	Low		
Operational Constraints							
Impact on current procedures or practices	Low/Medium/High	Low	Low	Low	High		
Technical Enablers							
Complexity	Low/Medium/high	Medium (fine tuning of alerts)	Medium				
Availability of Technologies	Available - 20XX						
EFS				available	available		
Conflict Detection		today	today	today			
Conflict Resolution							
CPDLC					2013-2020		
Flight Data Management				today			
HMI		today	today	available	available		
Dependencies to other services		Surveillance (with higher perf.)		Surveillance (Routing)	Routing		
Dependencies to aircraft equipment		Consistency with on-board alerts (if provided)		No change	CPDLC on-board		
Costs	Low/Medium/high	Medium (High if new SMR needed)		Low	High		
IMPLEMENTATION PHASE (START)	prior to 2013, prior to 2020, 2020 onwards	today - 2013	today - 2013	prior to 2013	2013-2020	not mature	not mature

Figure 3: Rating of Control Service Steps

3.2.6.2 Influence of Airport Characteristics

3.2.6.2.1 Traffic Level

Traffic level influences largely the adoption of control service steps 1, 2 from safety perspective and step 3 from efficiency of operations perspective (reduction of voice communications).
Airports with lower traffic compared to the generic case may not implement step 1, 2 or 3 due to their associated costs.

3.2.6.2.2 Airport Layout Complexity

Airport layout complexity is a contributing factor to runway incursions or deviations of Flight Crews from ATC clearances, as such it also influences the decision to implement the steps 1, 2 and 3 (earlier than compared to the generic case).

3.2.6.2.3 Number of LOW VIS days

Compared to other services (e.g. surveillance for ATCOs, moving map for Flight Crews) the control service alone does not deliver higher level of improvements in reduced visibility conditions. However, referring especially to step 1 of an alerting function, represents an essential enabler for the application A-SMGCS procedures under reduced visibility context (for more details refer to EMMA2 SPOR [1], section 3.3).

3.3 Routing / Planning Service

3.3.1 Step 1: Manual Routing

3.3.1.1 Description

Route assignment is done manually by ATCOs using an appropriate HMI that has to be flexible for destination and route changes.

3.3.1.2 Operational Improvements

The routing service is an enabler for the taxi route conformance monitoring part of the Control service as it enables the detection of non-conforming movements.

3.3.1.3 Operational Constraints

The implementation of this service could cause some extra workload for ATCOs, who have one additional task to perform (insert/edit route in the EFS or A-SMGCS)

3.3.1.4 Technical Enablers Availability and Complexity

The manual routing service represents a potential implementation step prior to the automation of switching-on/off taxiway segment lights along the route of aircraft. Compared to the current working methods the ATCO's role does not change since he/she has to communicate taxi clearances via R/T. A modified HMI integrated with EFS, where he/she can store/change/edit the cleared taxi route constitutes the main technical change.
The enablers needed are:

- a proper HMI to operate (generate, select, change, and assign) taxi routes for each movement
- Database of standard taxi route integrated in the system and accessible from the EFS

3.3.1.5 Ground Prerequisite for the implementation of Step 1 of the Routing / Planning service

None

3.3.1.6 Aircraft Prerequisite for the implementation of Step 1 of the Routing / Planning service

None

3.3.2 Step 2: Semi-automatic Routing

3.3.2.1 Description

This service gives additional information to ATCO while providing routing services. The routing service proposes the most suitable route, taking into account shortest taxi distance and current constraints (airport configuration).

3.3.2.2 Operational Improvements

This semi-automatic routing service generates some improvements in the efficiency and safety key performance areas. The semi-automated routing service provides, for each aircraft, the shortest taxi-route, ensuring efficient surface movements.
By analysing systematically the possible taxi route constraints on the airport layout (i.e. restricted areas, taxiway directions) the service prevents potential operational errors from ATCOs and Flight crews.

3.3.2.3 Operational Constraints

No relevant changes are planned on the procedures or practices currently in use by ATCO when implementing the semi-automatic routing service. The ATCO should communicate (via R/T) the taxi route calculated by the system to the Flight Crew requesting the clearance.
This service should allow a reduction in the ATCO workload (compared to routing step 1) since he/she receives the routing information from the system and after verification, communicates it to the Flight Crew.

In current procedures ATCOs generally do not write down or make inputs to a system when they change a taxi route. Therefore in the future, if an input is required to update a system-calculated route, it is important to minimise the number of changes to be made by ATCOs in order to maintain a reasonable workload level.

3.3.2.4 Technical Enablers Availability and Complexity

The semi-automatic routing service is the second step towards the implementation of the fully automatic routing service. Compared to the current working methods the ATCO's role does not change since he/she has to supply taxi clearance via R/T.
In addition to the enablers already identified for the manual routing services (see section 3.3.1), the following enablers are required:

- Routing algorithm, based on the following calculation criteria:
  - shortest distance
  - including airport configuration/traffic constraints
  - flexible to offer standard taxi route or alternatives if none of those proposed satisfies controller's needs
- Flight plan information: estimated departure / arrival time for pre-determination of taxi route
- Appropriate user friendly HMI, that is not time consuming for taxi route selection or searching for alternatives.

3.3.2.5 Ground Prerequisite for the implementation of Step 2 of the Routing / Planning service

- Surveillance Service Step 2 (aircraft position and identification on manoeuvring area and apron)

3.3.2.6 Aircraft Prerequisite for the implementation of Step 2 of the Routing / Planning service

None

3.3.3 Step 3: Automatic Routing

3.3.3.1 Description

ATCO is responsible for taxi clearance(s) but the service maintains automatically up-to-date the route (track) and timing information.
The flight planning (pre-tactical and tactical) function has to be added to increase efficiency of the routing services. Planning support can be further increased by the implementation of an automated departure management tool (DMAN) that provides an optimised departure sequence and (runway usage).

3.3.3.2 Operational Improvements

Medium improvements on the airport throughput and efficiency for surface movements are expected when implementing the routing service together with a planning function (i.e. DMAN). The automatic service should "elaborate" and supply the best taxi route, taking into account input coming from the planning function. This implies the opportunity of increasing the RWY throughput through better sequencing of surface movements for departure aircraft (queues at RWY holding points).

3.3.3.3 Operational Constraints

No additional operational constraints are identified compared to the previous step.

3.3.3.4 Technical Enablers Availability and Complexity

- Routing algorithm
    - shortest distance criteria
    - infrastructural/operational constraints
    - Minimizing crossing conflicts
- Appropriate user friendly HMI, that isn't time consuming for taxi route selection or searching for alternatives.
- DMAN
- EFS: report on the flight progress (i.e. timeline) indicating ETOT, CTOT and TSAT
- Airport configuration – operational procedures applied available in the system

3.3.3.5 Ground Prerequisite for the implementation of Step 3 of the Routing / Planning service

- **Surveillance service step 2** (aircraft position and identification on manoeuvring and apron area);
- Flight plan data processing system (to get ETOT, ELDT, CTOT, RWY, Gate/Stand, A/C Type);
- The A-SMGCS control function (to know about LVP, crossings and all other prevailing constraints).

3.3.3.6 Aircraft Prerequisite for the implementation of Step 3 of the Routing / Planning service

None

3.3.4 Rating of Service Steps

3.3.4.1 Generic Airport

The following table depicts the evaluation of the implementation service steps for the Routing / Planning service.

	Generic Airport	Step 1 **Manual Routing**	Step 2 **Semi-automatic Routing**	Step 3 **Automatic Routing**
Operational Improvements				
Airport Throughput Benefits	Low/Medium/High			Medium
Efficiency surface movements	Low/Medium/High	Indirect benefits	Indirect benefits	Medium
Safety Benefits	Low/Medium/High	Indirect benefits	Indirect benefits	Indirect benefits
Operational Constraints				
Impact on current procedures or practic	Low/Medium/High	Medium	Low	Low
Technical Enablers				
Complexity	Low/Medium/high			
Availability of Technologies	Available - 20XX			
Functional airport database			prior to 2013	prior to 2013
EFS			available	available
HMI for routing			prior to 2013	prior to 2013
Manual Routing				
Semi-automatic Routing Algorithm			prior to 2013	
Automatic Routing Algorithm				
A-CDM				option
DMAN (take-off sequencing)				option
Dependencies to other services		None	Surveillance Step 2	Surveillance Step 2
Costs	Low/Medium/high	Low	Low	Low to Medium
IMPLEMENTATION PHASE (START)	prior to 2013, prior to 2020, 2020 onwards	No implementation (ATCO extra workload)	prior to 2013	prior to 2013 (without DMAN) 2010-2015 (DMAN)

Figure 4: Rating of Routing / Planning Service

3.3.4.2 Influence of Airport Characteristics

The section addresses the potential variations (compared to generic airport) for the size of operational improvements or the timeframe for the implementation of service steps.

3.3.4.2.1 Traffic Level

Very few airports have implemented routing service step 1. Most of large European airports are going towards the full implementation of the service step 1 and 2, with the introduction of Electronic Flight Strips in the Tower. The traffic level is a major driver for their implementation; by this way, the ground traffic could be managed in a more expedite way.

3.3.4.2.2 Airport Layout Complexity

For airports with a complex layout, the routing service steps 2 and 3 are aimed to support safe and efficient surface movement operations through for the management of movements on the ground.

3.3.4.2.3 Number of LOW VIS days

Although the routing service does not allow the same traffic level to be maintained in low visibility conditions (VIS COND 3 and 4) compared to normal visibility (procedural control still applied), it fully contributes to these type of operations and is therefore implemented with priority at airports confronted with a high number of LOW VIS days.

3.4 Guidance Service

3.4.1 Step 1: Manually-operated Ground-based Guidance

3.4.1.1 Description

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

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

These visual aids provide clear indications to flight crews and vehicle drivers to allow them to follow their assigned routes.
The ATCO has to switch on/off lights **manually** for ground guidance to flight crews.

3.4.1.2 Operational Improvements

Medium benefits on airport throughput, on surface movement efficiency and on safety are expected only in low visibility. Flight Crews and vehicle drivers can follow lighting indications to reach the final destination, allowing an expeditious traffic flow while keeping a high level of safety. This service could generate some changes in the operational procedures, avoiding/reducing for instance the number stops at IHP when you are in low visibility, then increasing the number of aircraft taxiing on airport surface.

3.4.1.3 Operational Constraints

This service could generate an increase in the ATCO's workload because they have to manually to switch on/off the lights guiding the Flight Crew/vehicle drivers to its final destination or to coordinate with the assistant in charge of the lighting system.

3.4.1.4 Technical Enablers Availability and Complexity

Technical enablers needed for the implementation of this service are already available on the market and they are:

- Airfield Lighting Control System, segment-wise switchable centre line lights;
- Stop-bars;
- Selectively switchable Centre Line Lights and Stop Bars;
- Ad-hoc interfaces that allow the controllers to manage visual aids for automated guidance and control along the assigned route;

The required technology is simple and can be easily found on the market, but considerable investments are required to ANSPs (and airport operators) to upgrade/change their systems.

3.4.1.5 Ground Prerequisite for the implementation of Step 1 of the Guidance service

- nothing – the service can be operated manually without support of any A-SMGCS service (e.g. London Heathrow)

3.4.1.6 Aircraft Prerequisite for the implementation of Step 1 of the Guidance service

None

3.4.2 Step 2: Automated Ground-based Guidance

3.4.2.1 Description

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

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

This provides clear indications to flight crews and vehicle drivers to allow them to follow their assigned routes and it is operated by the A-SMGCS based on the clearances input by the ATCO

3.4.2.2 Operational Improvements

Medium benefits on airport throughput, are expected in reduced visibility since the number of intermediate holdings and Flight Crew reports to ATCOs can be reduced. Moreover, the service prevents navigation errors by Flight Crews and thus contributes to the efficiency and safety of surface movements.

3.4.2.3 Operational Constraints

No constraints have been identified for this service step provided that automation ensures that decisions of ATCOs are associated with switch-on/off actions of taxiway lighting segments or stop bars.

3.4.2.4 Technical Enablers Availability and Complexity

The main required enablers are:

- Automated Airfield Lighting Control System (segment switchable lights),
- Controller HMI (Switchboard or Lighting Display),
- Interfaces to Control and Surveillance Function,

Development plans schedule to deliver the required enablers on the medium term (2013-2020).
It shall be noted that the ground lighting is part of the aerodrome infrastructure and is implemented in relation to the landing system selected (ILS CAT-I to CAT-III).

3.4.2.5 Ground Prerequisite for the implementation of Step 2 of the Guidance service

- Surveillance service step 2 (aircraft position and identification on manoeuvring and apron area)
- Routing service step2 (semi-automatic routing)

3.4.2.6 Aircraft Prerequisite for the implementation of Step 2 of the Guidance service

None.

3.4.3 Rating of Service Steps

3.4.3.1 Generic Airport

The following table depicts the evaluation of the implementation service steps for the Guidance service.

	Generic Airport	Step 1 **Manual Operation of Ground based Guidance Means Equipment**	Step 2 **Automatic Operation of Ground based Guidance Means**
Operational Benefits			
Airport Throughput Benefits (if demand exists)	Low/Medium/High	Medium (in low vis)	Medium (in low vis)
Efficiency surface movements	Low/Medium/High	Medium (in low vis)	Medium (in low vis)
Safety Benefits	Low/Medium/High	Medium (in low vis)	Medium (in low vis)
Operational Constraints			
Impact on current procedures or practices	Low/Medium/High	Coordination with assistant in charge of lighting system.	Low
Technical Enablers			
Complexity	Low/Medium/high		
Availability of Technologies	Available - 20XX		
Airfield Lighting Control System		today	
Automatic Airfield Lighting Control System			2013-2020
Selectively switchable Centre Line Lights and Stop Bars		available	not needed
Controller HMI (Switchboard or Lighting Display),		available	same HMI as for Taxi CPDLC
Dependencies to other services		None	Routing Surveillance
Costs	Low/Medium/high	High	High
IMPLEMENTATION PHASE (START)	prior to 2013, prior to 2020, 2020 onwards	Prior to 2013 for stop bars No implementation for manually segment-wise switchable centerline lights at generic airport	2013 - 2020

Figure 5: Rating of Guidance Service

3.4.3.2 Influence of Airport Characteristics

The section addresses the potential variations (compared to generic airport) for the size of operational improvements or the timeframe for the implementation of service steps.

3.4.3.2.1 Traffic Level

The need to maintain an optimal airport throughput in reduced visibility conditions (VIS COND 3 and 4) is a major driver for the implementation of the guidance service.

3.4.3.2.2 Airport Layout Complexity

For airport with complex layout, the guidance services (especially step 2) could be of big support for the management of movements on the ground in low visibility conditions and on a complex layout, increasing by this way the number of aircraft taxiing on the manoeuvring area, then increasing the number of aircraft ready at runway holding points.

3.4.3.2.3 Number of LOW VIS days

Although the guidance service does not allow the same traffic level in low visibility conditions (VIS COND 3 and 4) to be maintained compared to normal visibility (procedural control still applied), it fully contributes to these type of operations and is therefore implemented with priority at airports confronted with a high number of LOW VIS days.

4 Implementation of the Services to Flight Crews

4.1 Description of Implementation Steps

The services for Flight Crews have been decomposed into a series of implementation steps during the EMMA project. The description of the associated on-board functions summarised below is extracted from the EMMA2 SPOR document.

4.1.1 Step 1: Airport Moving Map Function and Surface Movement Alerting (SMA)

4.1.1.1 Description

The Airport Moving Map function supports the Flight Crew during surface movement operations by improving their situational awareness about own-ship position and heading on the aerodrome layout.
The Surface Movement Alerting (SMA) function will be a safety support tool to avoid runway incursions by preventing the unauthorised entrance, crossing of runways as a result of Flight Crew navigational errors

4.1.1.2 Operational Improvements

- Significant safety benefits: reduction of runway incursions particularly on complex airport layouts, especially in cases where Flight Crews are not familiar with the respective airport.
- Efficiency of surface movements: the situational awareness provided by the moving map will improve adherence to taxi clearances thus avoiding non safety critical taxi errors, which have an impact on the efficiency of surface movements.

4.1.1.3 Operational Constraints

Besides changes in standard operating procedures no major constraint for the Flight Crew. The airport database will need to be updated periodically (AIRAC cycle).

4.1.1.4 Technical Enablers Availability and Complexity

Two enablers are identified (both available today):

- Digital database of the airport surface using adequate data format for instance ARINC 816 format
- Required high accuracy of aircraft position (under evaluation)

4.1.1.5 Dependencies to other A-SMGCS services

- Database upload performed offline (i.e not in flight), see SPOR [1] section 2.2.8

4.1.1.6 Dependencies to ground equipment

None

4.1.2 Step 2: Ground Traffic Display and Conflict Detection

4.1.2.1 Description

The Ground Traffic Display function enhances the traffic situational awareness on-board through the display of other aircraft / vehicles respective positions, identity and headings.

The Conflict Detection function raises the awareness of the Flight Crew about potential conflict(s) with other traffic.

4.1.2.2 Operational Improvements

Significant safety benefits: a major operational improvement will come into effect by a timely warning on potentially dangerous encounters with other aircraft/vehicles thus preventing ground collision with other traffic if a respective warning or instruction by the respective ATCO was not provided.
The Ground Traffic Display and Conflict Detection Function in no way will substitute the respective ATCOs responsibility for control of the relevant traffic.
.

4.1.2.3 Operational Constraints

Because the ATCO remains responsible for avoiding such occurrences no immediate constraints.

New standard operating procedures for Flight Crews will have to be implemented, e.g. when an on-board generated warning was not communicated by ATCO.

4.1.2.4 Technical Enablers Availability and Complexity

- ADS-B In, for reception of other aircraft/vehicles position (available today).
- ADS-B Out, emission of position of each aircraft/vehicles position: available today but expected to be on all aircraft in 2020+
- TIS-B : technology is available but no plan for deployment exists today

4.1.2.5 Dependencies to other A-SMGCS services

- Ground surveillance providing information traffic.
- ADS-Out provided by other traffic, (for all aircraft 2020+)
- Airport moving Map function

4.1.2.6 Dependencies to ground equipment

- TIS-B ground station (if deployment of TIS-B in Europe)

4.1.3 Step 3: TAXI-Controller Pilot Data Link Communication (TAXI-CPDLC)[1]

4.1.3.1 Description

The TAXI-CPDLC services support the Flight Crew for ATC Controller – Flight Crew dialogs during surface movements (start-up, push-back, taxi clearances) and the reception of taxi route information dispatched by the ground system. At a later stage it is envisaged that clearances such as taxi route revisions or hold short instructions will be communicated using CPDLC as well.

4.1.3.2 Operational Improvements

The TAXI-CDPLC services will improve safety enabling the flight crew to visualise and check the ATC taxi clearance through the airport moving map display. The efficiency of the surface movement will also indirectly be increased.

4.1.3.3 Operational Constraints

New Standard Operating Procedures of CPDLC exchange between the Flight Crew and ATC have to be defined and implemented to enable TAXI-CPDLC for ground operations..

4.1.3.4 Technical Enablers Availability and Complexity

- A proper data link that fits the performance needs for TAXI-CPDLC
- Airport moving map with enhancement features, including TAXI-CPDLC function in order to check graphically the TAXI-CPDLC message.
- Functional digital airport database, ref. 4.1.1
- TAXI-CPDLC communication interface and respective HMI

4.1.3.5 Dependencies to other A-SMGCS services

The CDPLC services are dependant on the use of two ground services:

- Control ground services in particular Step 3, see section 3.2
- Routing ground services, see section 3.3

4.1.3.6 Dependencies to ground equipment

- Air-ground data link communication system

[1] By the EUROCAE WG78 and the EUROCONTROL DUG it is called „D-TAXI“. The concepts are rather similiar because they have been worked out in parallel and with the needed exchange between the EUROCONTROL CASCADE programme and EMMA2. Nevertheless, there are also differences in terms of messages and recommended procedures. That’s why EMMA2 decided for the name „TAXI-CPDLC“.

4.1.4 Step 4: HUD Surface Guidance

4.1.4.1 Description

The Head-Up Navigation Subsystem is an avionic function that is designed to support the Flight Crew , e.g. during taxi operations. The concept for the Surface Guidance Symbology Function on the HUD is that it provides through adapted symbology tactical support to the Flight Crew; the HUD Surface Guidance is complementary to other on-board applications that provide general surface situation awareness information.

4.1.4.2 Operational Improvements

The HUD Surface Guidance reduces the head-down time of the respective flight crew steering the aircraft thus assisting him in navigation on the airport surface more efficiently by looking outside.

4.1.4.3 Operational Constraints

Standard Operating Procedures have to be modified to take into account the use of the HUD

4.1.4.4 Technical Enablers Availability and Complexity

- Head Up Display (for ground movement assistance)
- Functional Digital airport database

4.1.4.5 Dependencies to other A-SMGCS services

In order to fully support taxi movements the HUD Surface Guidance needs to obtain the cleared taxi route via the TAXI-CPDLC service , see 4.1.3. Basic support of taxi movements (breaking-steering actions) may also be provided without requiring TAXI CPDLC.

4.1.4.6 Dependencies to ground equipment

- TAXI-CPDLC service for full support of taxi movements

4.1.5 Step 5: Optimised Runway Occupancy System and Steering Cues

4.1.5.1 Description

The Braking and Steering Cues (BSC) display subsystem is an avionic function that will support the Flight Crew 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 optimise the runway occupancy times, by assisting the Flight Crew to control the 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.
- Steering and braking support to the Flight Crew during taxi operations. Examples where the BSC function will contribute to taxi operations include:
  - Braking cues in the event that taxi speeds are too high approaching a turn
  - Steering cues for taxi manoeuvres
- Speed-control cues to allow the Flight Crew to increase speed where appropriate to reduce overall taxi time whilst minimising wear and tear on the undercarriage.

4.1.5.2 Operational Improvements

The Braking and Steering Cues function could reduce the runway occupancy time of each aircraft.
When this function will be utilised at a significant rate the runway capacity could be increased, providing substantial benefits to the airport capacity, moreover, this function brings a more efficient surface movement.

4.1.5.3 Operational Constraints

The preferred runway exit point as defined by the ATCO must be known by the Flight Crew sufficiently early during the approach and landing in order to programme the on-board system.

4.1.5.4 Technical Enablers Availability and Complexity

- On-board HMI or Head Up Display (option),
- Required high accuracy of aircraft position if HUD used

4.1.5.5 Dependencies to other A-SMGCS services

HUD, eventually TAXI-CPDLC

4.1.5.6 Dependencies to ground equipment

None, eventually TAXI-CPDLC

4.1.6 Step 6: Ground-Air Database Upload

4.1.6.1 Description

The Ground-to-Air Database Upload Function is required to ensure that aircraft are operating 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.

4.1.6.2 Operational Improvements

Safety Improvement: by uploading the latest version of the aerodrome database the Flight Crew will be relieved of having to manually track changes to aerodrome charts (e.g. unidirectional taxiways, restricted areas), reading relevant airport NOTAMs, and thus the risk of inconsistencies (between ATC and on-board data) is mitigated.

The service also allows a reduction of relevant maintenance work on database updates.

4.1.6.3 Operational Constraints

None

4.1.6.4 Technical Enablers Availability and Complexity

- Database upload function ensuring a secure transfer of data
- Large band with for aeronautical data communication (might not be feasible before 2020)

4.1.6.5 Dependencies to other A-SMGCS services

Data-Link function

4.1.6.6 Dependencies to ground equipment

- Airport database server
- Data-Link

4.2 Rating of Implementation Steps

	Generic Airport	Step 1 **SMA, Airport Moving Map**	Step 2 **Ground Traffic Display, Conflict Detection**	Step 3 **Taxi CPDLC (graphical)**	Step 4 **HUD Surface Guidance**	Step 5 **Optimised runway occupancy system Steering Cues**	Step 6 **Air-Ground Database Upload**
Operational Benefits							
Airport Throughput Benefits	Low/Medium/High	Medium				High (if significant equipage rate)	
Efficiency surface movements	Low/Medium/High	Medium	Low	Medium (added to AMMD)	Medium	High (if significant equipage rate)	
Safety Benefits	Low/Medium/High	High	High	Medium (Added to AMMD)		Low	High
					Medium decrease High decrease in Low Vis Con.		
Operational Constraints							
Impact on current procedures or practices (SOP)	Low/Medium/High	Low	Low	Medium	High	Low	Medium
Impact on Pilot workload		Low decrease	Low increase	Medium increase	Reduction head down	Low increase	Medium decrease
Technical Enablers							
Complexity	Low/Medium/high						
Availability of Technologies	Available - 20XX						
Digital Airport Database		prior to 2013	prior to 2013	prior to 2013	prior to 2013	prior to 2013	Prior to 2013
Functional Airport Database				prior to 2013	prior to 2013	prior to 2013	
High Position Accuracy and Integrity(<10m)		prior to 2013				very high positioning (prior to 2020)	
ADS-B-in and TIS-B fusion			available				
CDTI			available				
CPDLC communicationss (integrated to Airport Moving Map)				prior 2020			
HUD					available	option	
Large bandwidth comm network for aeronaut. Information							2020+
Dependencies to other A-SMGCS services			Surveillance (if TIS-B used) ADS-B OUT	Routing Control	Routing Taxi CPDLC	HUD Surface Guidance eventually Taxi CPDLC	availibility of secured data uploads
Costs	Low/Medium/high	Medium	High	High	High	High	High
IMPLEMENTATION PHASE (START)	prior to 2013, prior to 2020, 2020 onwards	today-2013	2020+ (for all a/c ADS-B-out) Prior to 2020 if TIS-B available	2013-2020	Prior to 2013 (basic taxi functions) 2013-2020 (full support to taxi movements)	Today-2013 (Brake to Vacate, steering assistance) 2013-2020 (autobrake, autosteer)	2020+

Figure 6: Rating for Services to Flight Crews

5 Definition of A-SMGCS Services Roadmap

5.1 Decisions – Rationale

The analysis made for the list of A-SMGCS services proposed by EMMA2 considering the generic airport case (see 2.2) led to:

- Allocate time-scales for the implementation of service steps (prior to 2013, 2013-2020, 2020+)
- Investigate dependencies between A-SMGCS services for their coordinated and incremental deployment

Several A-SMGCS service steps proposed by EMMA2 SPOR have not been retained for the implementation roadmap:

- Manual routing function (Routing service): deemed as too time consuming for ATCOs
- (Automated) Conflict resolution for ATCOs (Control service): feasibility not confirmed by EMMA2 partners

In the case of the generic airport one A-SMGCS service steps was not retained:

- Provision of manually-operated ground-based guidance: deemed as too expensive (extra human resource required) for the type of airport

5.2 Implementation Roadmap for the Generic Airport

The implementation roadmap for A-SMGCS services is presented along 2 views:

- Timeline for services implementation: operational availability before 2013, between 2013 and 2020, after 2020
- Sequence for services implementations: steps and dependencies for A-SMGCS services

5.2.1 Timeline for A-SMGCS Service Implementation

The following figure depicts the schedule for the operational availability of the different A-SMGCS services as a result of the stepped deployment of A-SMGCS services (and dependencies between services) and the timeframe required for their development (availability of technical enablers).

Service	Service Steps	Implem. Start	2008	2013	2020
SURVEILLANCE					
Step1	Manoeuvring Area (aircraft and vehicles)	today			
Step2	Step 1 + Apron Area for aircraft	today			
Step3	Step 2 + Apron area for vehicles	today			
Step4	Manoeuvring + Apron using altern. technologies (ADS-B)	2020+ (delay required for full equipage)			
CONTROL					
Step1	RWY Conflict Detection and Alerting	today - 2013			
Step1 extension	TWY Conflict Detection and Alerting	today - 2013			
Step2	Conflict Prediction and Alerting (traffic and clearance conformance monitoring)	prior to 2013			
Step3	TAXI-CPDLC	2013-2020			
Step4	Conflict resolution (proposal of the solution)	not mature			
Step5	Conflict resolution (resolution)	not mature			
ROUTING					
Step1	Manual Routing	No implementation (ATCO extra workload)			
Step2	Semi-automatic Routing	prior to 2013			
Step3	Automatic Routing	prior to 2013 (without DMAN) 2010-2015 (DMAN)	**w/o DMAN**	**with DMAN**	
GUIDANCE					
Step1	Manual Operation of Ground based Guidance Means Equipment available on the market	Prior to 2013 for stop bars No implementation for manually segment-wise switchable	**Stop bars only**		
Step2	Automatic Operation of Ground based Guidance Means	2013 - 2020			
AIRCRAFT					
Step1	SMA, Airport Moving Map	today-2013			
Step2	Ground Traffic Display, Conflict Detection	2020+ (for all a/c ADS-B-out) Prior to 2020 if TIS-B available		**TIS-B required**	**ADS-B only**
Step3	Taxi CPDLC (graphical)	2013-2020			
Step4	HUD Surface Guidance	Prior to 2013 (basic taxi functions) 2013-2020 (full support to taxi movements)	**Basic taxi functions**	**Full taxi support**	
Step5	Optimised runway occupancy system	Today-2013 (Brake to Vacate,			
Step6	Air-Ground Database Upload	2020+			

Figure 7: Timeline for A-SMGCS Services Implementation

5.2.2 Sequence for A-SMGCS Services Implementation

The following section addresses the identified dependencies for the implementation of A-SMGCS services, either between A-SMGCS service steps or dependencies on technical enablers (ground or aircraft systems, air-ground data link technologies).

5.2.2.1 Overview of Implementation Sequence

Figure 8 depicts the sequence for the implantation of A-SMGCS service steps covering:

- the dependencies between the A-SMGCS services ('Enables' relationships)
- the incremental deployment of A-SMGCS services through steps of increasing complexity ('Extended by' relationships)

5.2.2.2 Short Term Implementation (prior to 2013)

On the ATCO side the provision of ground-based safety nets and the support to tactical decision making built on top of the surveillance services is made.
On the Flight crew side the implemented services concern the support to the navigation on the airport layout and for braking action on the runway.
No additional data link between ground and aircraft system is required during the short term period.

5.2.2.3 Medium Term Implementation (2013 – 2020)

Medium term additional services are deployed to support the planning of surface movement by ATCOs and their execution by Flight Crews through coordinated information exchanges between ATC systems on one side and between ATC systems and aircraft systems on the other side. The deployment of new air-ground data link services and the supporting communication infrastructure (ATN network) is required.

5.2.2.4 Long Term Implementation (2020 onwards)

On the long term the previous services are completed by the provision of the traffic situation picture, additional on-board safety nets are made available to Flight Crews. The existing services to Flight Crews are enhanced through the automated upload of up-to-date airport configuration data.

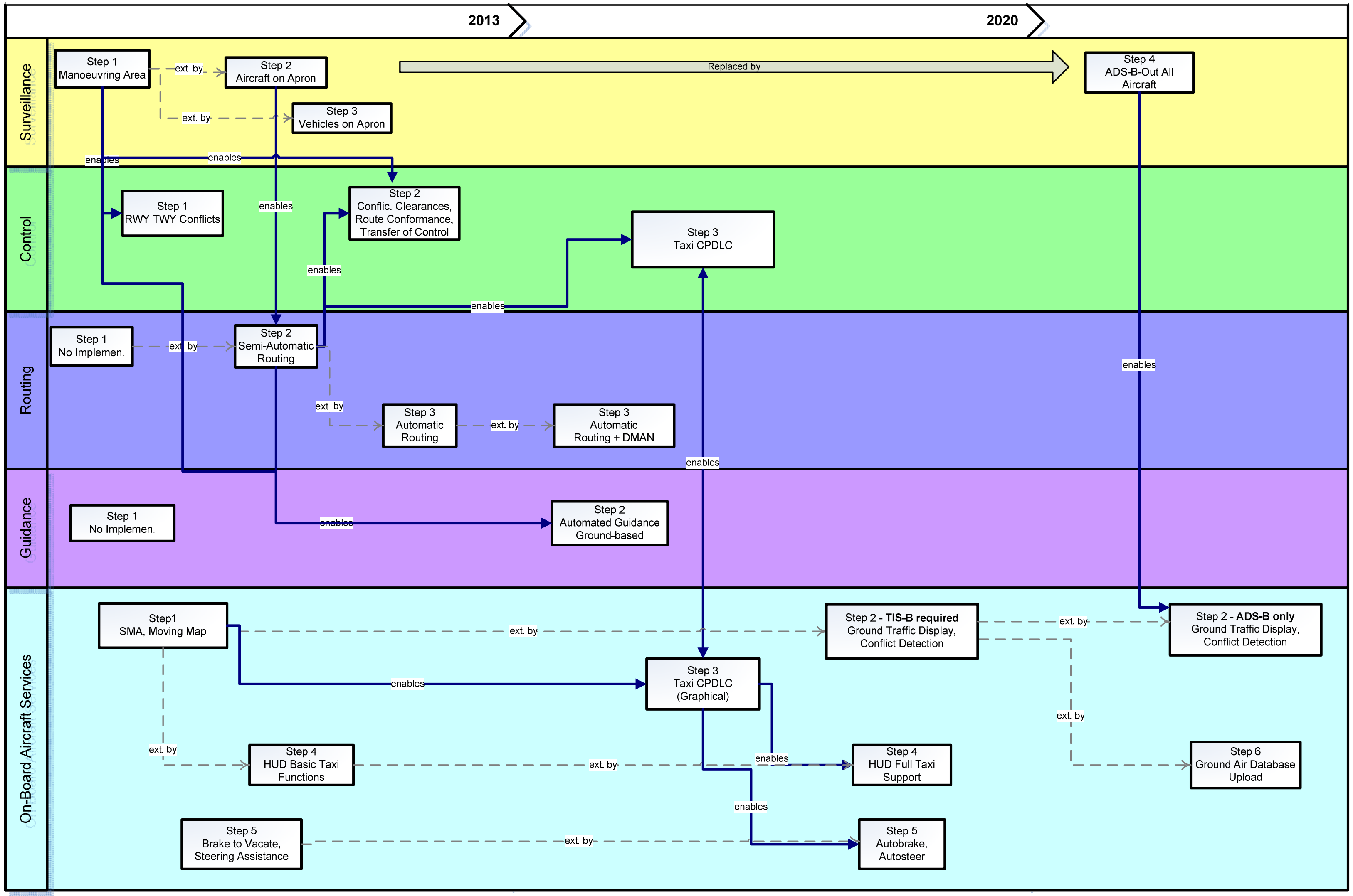

Figure 8: Sequence for the implementation of A-SMGCS Services (generic airport)

5.3 Influence of Airport Characteristics

The potential changes to the implementation roadmap for the generic airport case due to the influence of several airport characteristics, traffic density, layout complexity and number of low visibility days has been assessed for each service to ATCOs (see sections 3.1.5.2, 3.2.6.2, 3.3.4.2, 3.4.3.2)
The following table summarises the main impact of the key airport characteristics on the implementation of A-SMGCS services:

	Influence of Airport Characteristics		
Services to ATCOs	Traffic Level	Layout Complexity	No of Low Visibility Days
Surveillance	Earlier implementation of service steps 1, 2, 3 for airports with higher traffic level or more complex layout or higher number of low visibility days (compared to the generic airport case)		
Control	Earlier implementation of service steps 1, 2 for airports with higher traffic level or more complex layout or higher number of low visibility days (compared to the generic airport case) No change to step 3 (TAXI-CPDLC) as it depends primarily on the aircraft equipage (Service Step 3 for Flight Crews)		
Routing	Earlier implementation of service steps 2, 3 for airports with higher traffic level or more complex layout or higher number of low visibility days (compared to the generic airport case)		
Guidance	Implementation of segment switchable guidance lights is only foreseen for airport with high number of low visibility days and high traffic level or complex layout.		

Table 2: Impact of Airport Characteristics on Services to ATCOs (Summary)

5.4 Comparison with SESAR Operational Improvements Steps

5.4.1 The SESAR Context

As described in the SESAR Definition Phase Deliverable D4 "ATM Deployment Sequence", the SESAR ATM Target Concept is classified into Lines of Changes (LoC), which describe the main areas, which need to be further enhanced to reach the implementation of the SESAR ATM Target Concept.

The specific and detailed changes required to transition from today's system have been structured in a series of Operational Improvement (OI) Steps, defined along the LoCs. A detailed transition path from today onwards has been developed.

The OI Steps have been allocated to one of the three Implementation Packages (IPs) as defined in the SESAR D4 (cf. Reference 8), depending upon their start of operation:

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

5.4.2 The Roadmap and SESAR Operational Improvements (OIs)

The following table shows the Operational Improvements that will be brought by the development of the EMMA2 A-SMGCS services described in the roadmap.

LoC code	OI Code	OI Title	IP	A-SMGCS Service (EMMA2)
L08	AUO-0401	Air Traffic Situational Awareness (ATSAW) on the Airport Surface	IP1	Surveillance + Aircraft Ground Traffic Display
L10	AO-0102	Automated Alerting of Controller in Case of Runway Incursion or Intrusion into Restricted Areas	IP1	Surveillance Control
L10	AO-0104	Airport Safety Nets including Taxiway and Apron	IP2	Surveillance Control *EMMA2 prior to 2013*
L10	AO-0201	Enhanced Ground Controller Situational Awareness in all Weather Conditions	IP1	Surveillance Control Routing (DMAN)
L10	AO-0605	Automated Alerting of Runway Incursion to Pilots (and Controller)	IP2	Surveillance Control Aircraft *EMMA2 2020+ for Aircraft due to ADS-B*
L10	AO-0203	Guidance Assistance to Airport Vehicle Driver	IP1	Vehicle
L10	AO-0204	Airport Vehicle Driver's Traffic Situational Awareness	IP2	Vehicle
L10	AO-0205	Automated Assistance to Controller for Surface Movement Planning and Routing	IP2	Routing
L10	AO-0206	Enhanced Guidance Assistance to Airport Vehicle Driver Combined with Routing	IP2	Vehicle
L10	AO-0207	Surface Management Integrated With Departure and Arrival Management	IP2	Routing
L10	AUO-0602	Guidance Assistance to Aircraft on the Airport Surface	IP1	Aircraft Control
L10	AUO-0603	Enhanced Guidance Assistance to Aircraft on the Airport Surface Combined with Routing	IP1	Aircraft
L10	AUO-0604	Enhanced Trajectory Management through Flight Deck Automation Systems	IP2	Aircraft
L10	AUO-0702	Brake to Vacate (BTV) Procedure	IP1	Aircraft
L10	AUO-0703	Automated Brake to Vacate (BTV) using Datalink	IP2	Aircraft Control
L10	AUO-0403	Enhanced Vision for the Pilot in Low Visibility Conditions	IP2	Aircraft

Table 3: Correspondence with SESAR Operational Improvements

5.4.3 Use of the Roadmap during SESAR Development Phase

The roadmap for the deployment of A-SMGCS at European airports presented in this document contains several inputs for the SESAR development programme as described below:

- **Division of A-SMGCS Services in incremental steps**

The A-SMGCS services to ATCOs and Flight Crews have been divided into a set of incremental steps for their coordinated implementation at airports and in aircraft. Each step of implementation is characterised by its related operational benefits, the maturity of technological enablers and is positioned against the 3 main implementation phases of the European ATM Master Plan (prior to 2013, 2013-2020, post 2020). This structure provides an industry view of the deployment of A-SMGCS services combining operational and technical perspectives.

The main value of this division for the SESAR programme is to serve as a reference for the refinement of the SESAR ATM Target Concept. The roadmap already provides a service-based architecture for the planning and execution of airport surface movements that is in line with the recommendations of the SESAR Joint Undertaking for the development Phase. Such reference will be used to introduce key elements of the ATM Target Concept (i.e. Business/Mission Trajectory) and derive from the list of high-level operational improvements (see **Error! Reference source not found.**) the series of fine-grained units of deployment (operational and technical services).

- **Analysis of key performance targets**

The roadmap provides for each step of implementation the potential operational benefits gained as well as the main anticipated constraints. Such assessment has been conducted using the qualitative or quantitative results obtained at EMMA2 test airports and considering a generic example for European airports.

The main value for the SESAR Programme is to re-use such assessment (and the EMMA2 test results) for the refinement of the SESAR key performance targets (high-level) set for the Implementation Package 2 (IP2). This will allow to specify the required performances for the planning and execution of airport surface movement operations (quality of service at operational level) and to allocate these requirements to the appropriate A-SMGCS services (and service steps).

- **Overall picture for services, implementation steps and service dependencies**

The roadmap provides an overall view of the deployment of A-SMGCS using a service-based approach addressing ATC and Aircraft Operators perspective and covering the different technical increments for ground and aircraft systems foreseen by Industry representatives and their dependencies.

The main value for the SESAR Programme is to use this technical framework to maintain a consistent overall picture of the different units of deployment (operational and technical services) along the proposed timeframe for deployment, highlighting the associated transitions and keeping track of the dependencies. The roadmap offers a sound basis to consolidate and cross-check the findings and results of the different individual SESAR projects against a common reference.

6 Conclusions

The roadmap for the implementation of A-SMGCS services at 2008-2013, 2013-2020 and 2020+timeframes has been prepared by EMMA2 partners. At this stage it only represents an initial view of the operational availability of the EMMA2 services at ECAC airports in line with the SESAR Master Plan for European ATM.

The roadmap has been established by considering:

- Deployment of service steps (increments)
- A set of qualitative decision criteria used for rating the services individually
- Availability of technological enablers and dependencies between automated systems
- One generic airport case and a set of key airport characteristics influencing A-SMGCS implementation.

The proposed roadmap is built using a number of early estimates for the size of operational improvements or related costs and timescales required for service development. It will need to be maintained when more accurate figures become available.

7 Annex I

7.1 References

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[2] **ICAO**, *Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual*, Doc 9830 AN/452, First Edition, 2004.
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[7] **EMMA D6.7.1,** Verification &Validation Analysis Report V1.0 2006
[8] **SESAR D4,** The ATM Deployment Sequence, DLM-0706-001-02-00-January 2008

7.2 List of Figures

7.3 List of Tables