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Recommendations Report

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DLR

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1 Executive Summary

The project “European Airport Movement Management by A-SMGCS” (EMMA), an Integrated Project launched by the European Commission in its sixth framework programme, was executed between March 2004 and April 2006. The aim of the EMMA project was to mature and validate the A-SMGCS concept levels 1&2 by setting de facto standards for A-SMGCS systems and their operational usage and by the streamlining of existing products. The EMMA project brought A-SMGCS one further step towards the harmonised European implementation of A-SMGCS.

In close cooperation with EUROCONTROL, the advanced operational concept for A-SMGCS levels 1&2 has been proven and strengthened by the implementation of levels 1&2 A-SMGCS and extensive validation and verification (V&V) activities at three different European airports: Milano-Malpensa, Prague-Ruzyně, and Toulouse-Blagnac. In Prague-Ruzyně, controllers went as far as to work with the system in low visibility conditions, although this was not expected within the time-frame of the EMMA project. Measurement indicators and test procedures were defined and a significant amount of data was collected during the functional and operational tests. Controllers and pilots actively participated and contributed to the results. The analysis resulted in detailed recommendations covering:

- the concept of an A-SMGCS levels 1&2,
- the technical and operational requirements,
- procedures,
- implementation issues (e.g. safety assessment, training and licensing), and
- detailed recommendations for a harmonised A-SMGCS V&V methodology.

Further on, this document provides detailed recommendations to the respective stakeholders (i.e. users, R&D institutions, industry, and the European Commission as the contractor).

In an additional innovative study, a preliminary concept and an implementation roadmap for a complete A-SMGCS, considering higher-level services like routing, planning, and the air-ground integration, has been proposed to prepare the successor project EMMA2.

Summary of recommendations

In the following summary are listed the nine most important EMMA recommendations and ‘lessons learnt’:

EMMA R1 It is recognised that flight crews do not comply with the transponder operating procedures consistently even when they are published in AIPs and are known to the airlines. One main reason could be a non-standardised symbolism applied to the transponder control panels in cockpits of all kinds of manufacturers. It is recommended to include type/manufacturer specific procedures in the pre-flight preparation procedures/checklists and in the aircraft operations manual to further improve pilots’ compliancy.

EMMA R2 It is recommended, as was proven in EMMA, that, where the A-SMGCS provides an identification label for Mode-S equipped cooperating aircraft, air traffic controllers (ATCOs) can use the A-SMGCS surveillance display as a primary means for identification.

EMMA R3 In order to use the surveillance display safely and efficiently in all visibility conditions, it is recommended that all aircraft and vehicle movements, which intend to use the manoeuvring area, should be properly equipped to be co-operative with an A-SMGCS in order to provide their identity on the ATCO’s surveillance display.

- EMMA R4** Implementing A-SMGCS levels 1&2 at an airport requires intensive adaptation (tuning) to obtain a sufficient and reliable system performance. It is recommended that sufficient time and resources be allocated to this task.
- EMMA R5** It is recommended to tune the runway monitoring and alerting function (level 2) in a real-time simulation with local ATCOs before running it operationally at the airport.
- EMMA R6** It was found that the most useful means of assessing surveillance detection capability and coverage is to plot target position reports onto an aerodrome map over a period of time. This method clearly identifies areas with gaps in coverage and areas where false reports occur.
- EMMA R7** Some performance requirements are difficult to measure and verify by short-term testing only. Results are highly dependent on the measurement method and there are significant temporal variations. The EMMA tests indicate that verification of such requirements really needs continuous long-term observation over a period of several weeks. Automatic assessment tools, like the MOGADOR tool used in EMMA, may help here.
- EMMA R8** The use of a standardised and well-proven validation approach is recommended for achieving reliable and robust V&V results. The use of the MAEVA Validation Guideline Handbook [1] with its stepped evaluation view contributed substantially to the production of reliable validation results. In future validation projects, the European Operational Concept Validation Methodology (E-OCVM) [3] should be consulted as well.
- EMMA R9** The concept and implementation roadmap for a complete A-SMGCS, developed in EMMA (cf. [9]), are strongly recommended to take into account the current and future ATM master plans to build up an acceptable equilibrium between equipment, procedures and interoperability with the adjacent systems.

2 Introduction

With the two former European Commission framework programmes (FP4 and FP5), the DG-TREN co-funded two other large A-SMGCS implementation projects: DEFAMM (Demonstration Facilities for Airport Movement guidance control and Management) and BETA (operational Benefit Evaluation by Testing an A-SMGCS), aiming at the following levels of technological maturity:

- Demonstration of the A-SMGCS technology (DEFAMM);
- First A-SMGCS implementations under operational conditions to measure potential benefits (BETA).

In line with this evolutionary approach, FP6 introduced EMMA (European airport Movement Management by A-SMGCS) with the scope of initiating a *harmonised* implementation of A-SMGCS levels 1&2.

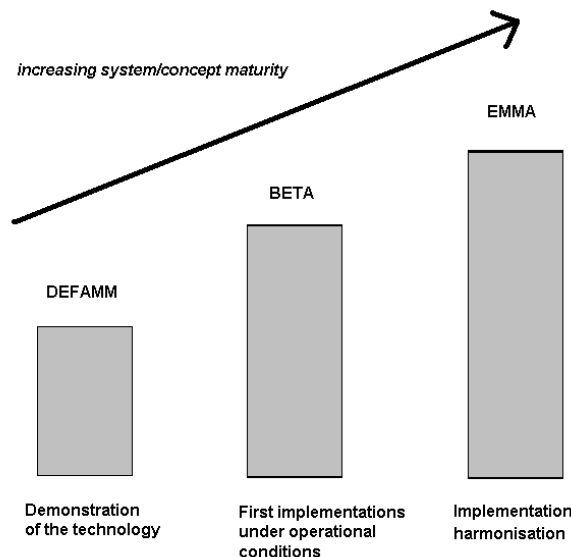


Figure 2-1: Projects' evolution

Within the EMMA project, A-SMGCS test-bed systems were installed, verified and validated at three different airports (Prague-Ruzyně, Toulouse-Blagnac, and Milano-Malpensa). The definition of common operational procedures, the verification of the technical performance and the validation of the use of the system are described in the EMMA operational concept documents (OSD [9] and ORD [11]) and in the analysis report [29].

This recommendation report aims in assisting to navigate through the different documents. It also derives the main conclusions to help service providers in installing their own A-SMGCS by following these recommendations, to avoid possible mistakes and to focus on site dependent constraints.

The report is divided into the following chapters:

- Chapter 3 Summary of EMMA concept and V&V results
- Chapter 4 EMMA Recommendations
- Chapter 5 Remaining open issues

3 Summary of EMMA concept and V&V results

3.1 EMMA concept for an A-SMGCS levels 1&2

The EMMA A-SMGCS concept is described in the following EMMA SP1 documents:

- the Operational Service and Environment Description (OSED) [9],
- the Operational Requirement Document (ORD) [11], and
- the Technical Requirements Document (TRD) [14].

All these documents make extensive references to the ICAO A-SMGCS Manual [31] and the EUROCONTROL A-SMGCS concept documents [5] [6]. The EMMA A-SMGCS implementations and V&V activities focussed on EUROCONTROL's levels 1&2 concept, although EMMA outlined a more comprehensive concept that also considers higher-level A-SMGCS services (e.g. planning, routing, and on-board services).

The EMMA A-SMGCS concept, which includes both operational requirements and associated procedures, has been set out in document D135u ORD [11]. The EMMA concept states:

“The objective of an A-SMGCS is to optimise the efficiency, capacity and safety of operations at an aerodrome. The surface movement infrastructure existing at many airports today can be enhanced by providing positive identification of traffic, improving all weather situation awareness, improving communications and navigation aids, and by providing route planning tools.”, §2.1 [11], (compare also ICAO doc 9830, §1.2 [31]).

Except for the *“improving communications and navigation aids by providing route planning tools”* aspects, which are higher-level A-SMGCS services to be covered in EMMA2, the above objective was proven with the EMMA A-SMGCS implementations in the simulator and on-site at the airports. For instance, the simulation trials revealed that A-SMGCS is able to reduce the average taxi time, the load of the R/T communication, and the controller's reaction time in case of a conflict situation (see §3 or [26] for more details).

These operational improvement objectives, which were measured on a real-time simulation test platform, could also be confirmed with controllers' subjective statements in the field. Controllers at Prague-Ruzyně were asked to estimate their perceived safety and efficiency when they work with A-SMGCS compared to earlier times when they did not use an A-SMGCS. Their positive answers and also the feedback from the shadow-mode trials with DSN and ENAV ATCOs at Toulouse-Blagnac and Milano-Malpensa showed that A-SMGCS provides significant operational improvements that will result in operational benefits for all stakeholders of an A-SMGCS (see [29] for more details). These results **validated the levels 1&2 concept of an A-SMGCS**.

3.2 EMMA Verification and Validation (V&V) results

At three test sites, Prague-Ruzyně, Toulouse-Blagnac, and Milano-Malpensa a levels 1&2 A-SMGCS has been implemented and tested. On-site trials were mainly used to verify that the implemented A-SMGCS fulfils the technical and operational requirements and to get feedback from the operators with respect to its operational feasibility.

Toulouse-Blagnac and Milano-Malpensa evaluated the A-SMGCS in shadow-mode trials, which provided important feedback to the technical and operational performance. Prague-Ruzyně already started with the earlier BETA project to implement an A-SMGCS and thus could rely on an already matured system. The controllers from Air navigation Services of the Czech Republic (ANS CR) used

the A-SMGCS in Prague operationally under all visibility conditions. At the time of the validation activities the ANS CR controllers had already used the A-SMGCS for more than seven months and thus were able to give experienced feedback about its operational feasibility and operational improvements.

In addition to that, real-time simulations were carried out with Prague ANS CR and Malpensa ENAV controllers by using traffic scenarios of their own airport environment. These simulation trials were mainly used to substantiate operational improvements with respect to safety and efficiency.

All the main technical and operational requirements could be verified (cf. [29]). For this purpose, technical short- and long-term measurements were conducted. The three systems implemented by EMMA could not always meet the levels of performance published in international standards (e.g. 99.90% probability of detection), but the controllers felt that the observed level of performance (e.g. 99.65% probability of detection measure in Prague-Ruzyně) was acceptable anyway.

For the long-term system performance measurements, the MOGADOR tool was used. MOGADOR is a tool developed by DSNM that fully automatically analyses surveillance performance parameters from long-term recordings of regular airport traffic (for more details cf. [8]). This tool provided interesting results that can also be used to tune and adapt the A-SMGCS to meet the operational needs.

The on-site trials at Prague revealed that controllers who have worked operationally with the A-SMGCS fully accepted the A-SMGCS and thus approved its “operational feasibility”. Statements like:

- “When visual reference is not possible, the displayed position of the aircraft on the taxiways is accurate enough to exercise control in a safe and efficient way.”, or
- “I think that the A-SMGCS surveillance display could be used to determine that an aircraft has vacated the runway.”, or
- “The information displayed in the A-SMGCS is helpful for avoiding conflicts.”, or
- “The A-SMGCS provides the right information at the right time.”, or
- “When visual reference is not possible I think the A-SMGCS surveillance display can be used to determine if the runway is cleared to issue a landing clearance.”

have been significantly confirmed by 15 ANS CR controllers (all results to be found in [26]). The statements mainly referred to the surveillance service of the A-SMGCS, because ATCOs in Prague-Ruzyně have not yet used operationally the full scope of the monitoring and alerting function, but only the “stop bar crossing” alerts as a first step. However, real-time simulations and real flight tests were used to create additional conflict situations (e.g. runway incursions, arrival-arrival conflicts, etc.). Results showed that the controllers also accepted the performance of the other alerts. Those results were also supported by the impressions of the ENAV (Malpensa) and DSNM (Toulouse-Blagnac) controllers who tested their systems in a passive “shadow-mode” environment (all results to be found in [27] and [28]).

Validation of operational improvements was mainly performed through real-time simulations (RTS). The most important unexpected result of the RTS was that **A-SMGCS is able to reduce the average taxi time**. In total, the average taxi time was reduced by 5.5% and showed to be statistically highly significant with 358 total movements [29]. Up to 18% taxi time reduction was measured in dense traffic scenarios.

Furthermore, **A-SMGCS reduces the load of the R/T communication**. With Prague RTS a statistically significant reduction of 16.0% was measured [29].

An additional operational improvement can be assumed with the **“controller’s reaction time in case of a conflict situation”**: **5.3 seconds with A-SMGCS instead of 6.0 seconds** without A-SMGCS.

The improved reaction time showed an interesting trend but was found to be statistically not significant. Further tests with a bigger sample size should reduce the ambiguity.

In the field, controllers were also asked to estimate their perceived safety and efficiency when they worked with A-SMGCS compared to earlier times when they did not use an A-SMGCS. The following main results were gained with Prague-Ruzyně controllers, which were all significantly and positively answered (all results to be found in [26]):

- “When procedures for LVO are put into action, A-SMGCS helps me to operate safer.”, or
- “I think A-SMGCS can help me to detect or prevent runway incursions.”, or
- “When visual reference is not possible, I think identifying an aircraft or vehicle is more efficient when using the surveillance display.”, or
- “I think, also in good visibility conditions, identifying an aircraft or vehicle is even more efficient when using the surveillance display.”, or
- “The A-SMGCS enables me to execute my tasks more efficiently.”, or
- “The number of position reports will be reduced when using A-SMGCS (e.g. aircraft vacating runway-in-use).”, or
- “The A-SMGCS enables me to handle more traffic when visual reference is not possible.”, or
- “The A-SMGCS display gives me a better situational awareness.”, or
- “When procedures for LVO are put into action, A-SMGCS helps me to reduce my workload.”

In shadow-mode field trials, performed at Toulouse-Blagnac and Milano-Malpensa, the DSNA and ENAV ATCOs also had an overall positive feeling about the ability of A-SMGCS to improve operations (see [29]). All those examples further support the hypothesis that A-SMGCS provides significant operational improvements that will result in operational benefits for all stakeholders of an A-SMGCS.

4 EMMA Recommendations

4.1 Recommendations related to the V&V process

The objective of the EMMA verification and validation (V&V) process was to assess the performance of the EMMA A-SMGCS on-board (aircraft and vehicles) and at the three project sites (i.e. Toulouse, Prague, and Malpensa). The experience and knowledge obtained during the EMMA project V&V process led to the development of the following main V&V recommendations:

- a) The use of a standardised and well-proven validation approach is helpful for achieving reliable and robust V&V results, and for reaching a consensus on the method within the consortium. The use of the MAEVA VGH (see Ref. [1]) with its stepped evaluation view contributed substantially to the production of reliable validation results. In future validation projects, the European Operational Concept Validation Methodology (E-OCVM, see Ref. [3]) should be used instead. The E-OCVM builds on the MAEVA stepped validation approach adding, amongst others, a lifecycle view to the validation process that helps to determine the necessary validation activities in each of the concept lifecycle phases. However, as the methodology does not describe verification, these activities have to be integrated into the validation approach.
- b) The development of a V&V master plan (see Ref. [17]) at an early stage of the project constitutes an essential prerequisite for organising and effectively managing the V&V process. In fact, the V&V master plan should ideally be part of the proposal itself.
- c) With EMMA, V&V has been split into four stages (cf. Figure 4-1), which proved very useful to organise V&V objectives.

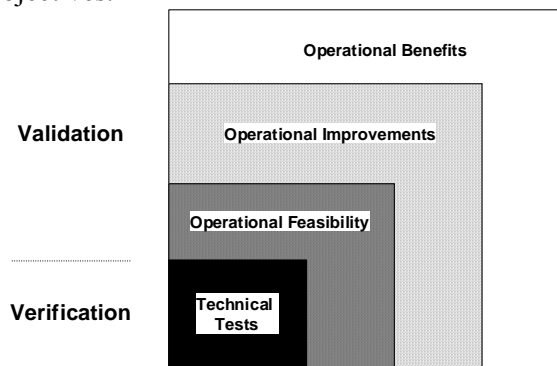


Figure 4-1: Stages of EMMA V&V activities

- d) Real-time simulation platforms proved to be appropriate means for testing non-nominal and safety-critical events, adapting technical parameters to the users' needs, and substantiating operational improvements in real experimental conditions. Field trials, on the other hand, are the irreplaceable means for proving the technical and operational feasibility of a new system.
- e) EMMA recommends using automatic long-term system performance assessment tools in the field to get support to verify and to tune the new level 1&2 system to meet the local specifics of an aerodrome.

The MOGADOR tool developed by DSNB has been refined within EMMA. The MOGADOR tool is an automatic system performance assessment tool that needs to know about local regulations and the airport environment in order to match the measured system surveillance output with the actual traffic. For this reason, the tool needs considerable adaptation to suit the airport specifics and the specifics of the used surveillance equipment in order to enable a correct automatic assessment of the system performance.

- f) For the purpose of analysis and to progressively update and improve the safety net settings, it proved to be useful to retain electronic records of the alerts and the traffic situation respectively.

4.2 Recommendations related to technical requirements

The EMMA technical requirements document D142au_TRD-GND [14] derived the most important requirements from the ICAO A-SMGCS manual [31], EUROCAE ED-87A [30], and EUROCONTROL levels 1&2 operational concept and requirements documents [5] [6], and put together a comprehensive list of technical requirements. These technical requirements were tested at all three test sites and most of them could be verified (cf. EMMA D671 V&V analysis report [29]).

Problems mainly arose with technical *surveillance* requirements that were derived from operational performance requirements. The surveillance requirements were tested by separate technical *short-term* and *long-term* tests using test cars, test aircraft, and automatic evaluation tools (e.g. MOGADOR). In that way, 18 technical tests were performed (see the detailed results in §2.4 in D671 [29]).

By comparison of the three test sites, it was recognised that a complete coverage of the aerodrome is frequently a challenging objective. Incomplete coverage is mainly observed because there is an insufficient quantity of sensors to provide line-of-sight detection of all aircraft and vehicles on the movement area. Possible mitigation means are additional “gap filler” solutions (e.g. camera systems), additional SMRs, and/or the introduction of operational regulations to allow only co-operative movements in certain movement areas, combined of course with the correct application of the transponder operating procedures at the on-board side.

A long and meticulous **tuning phase** is necessary to obtain adequate system performance. EMMA recommends not underestimating the time and effort required for the tuning phase with the implementation of A-SMGCS levels 1&2.

With such a tuning phase, EMMA further strongly recommends to plot target position reports onto an aerodrome map over a long period of time (at least one week) and to automatically analyse the surveillance results by comparing them with re-constructed (or expected) aircraft trajectories. This method clearly identifies areas with gaps in coverage and areas where false reports occur, whilst the plotting helps tuning the tool and explaining the inconsistencies. Automatic **long-term performance assessment tools**, like MOGADOR, which also provide matrices of detection and identification, are recommended.

4.3 Recommendations related to operational requirements

Operational requirements are the parent requirements for most of the technical requirements. Thus, most of the operational requirements have already been verified by technical tests or by a plausibility check, e.g. “The installed system shall be modular”.

Other operational requirements, particularly *performance* requirements, have an *interval* character, where a range of different performances is possible, but a minimum performance has been given that must be achieved. Such requirements are also easy to verify but sometimes hard to validate. Verification is done by technical tests whereby the measured performance is compared to the predefined minimum requirement. Even the operational feasibility of those performance requirements can easily be tested by asking the operators if they accept that the current performance is adequate for them to work with the system. However, to assess its validity, real experiments with different experimental treatments (different system performances) would be needed to decide whether even lower performance would be sufficient to meet the users’ needs.

Detailed results of all operational requirements by all three test sites can be found in the annex of document D671 *V&V Analysis Report* [29]. Most of the requirements have been verified by technical tests or checks. With some of them, the operational feasibility has been tested by asking the controllers who actively worked with the system. These additional results have been used either to fully verify the requirement, or to reject the system performance in this respect, or to question the requirement in terms of its validity.

4.4 Recommendations related to procedures

With A-SMGCS levels 1&2 mainly two procedures were changed: On the one hand, the ATCO aircraft identification procedure, and on the other hand, the pilot transponder operating procedure.

- a) With respect to the identification procedure given in D135u ORD §7.2 [11] and the EMMA V&V results, it can be stated that **ATCOs can use the A-SMGCS surveillance display as a primary means for identification**, where the A-SMGCS provides an identification label for every Mode-S equipped cooperating aircraft.

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 the controller with 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 for surveying 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 provides the position and the identification of all co-operative movements and the position of all non-co-operative movements superimposed on a map of the aerodrome. Radio telephony (R/T) reports from co-operative movements to inform the ATCO of their position or that they have vacated the runway are no longer necessary.

- b) The **pilot transponder operating procedures** were published by EUROCONTROL and shall allow aircraft to be automatically identified by an A-SMGCS (see §4 [11]).

ATCOs admitted that the *Transponder Operating Procedures* (as defined in the D135u ORD §4 [11]) are well-defined and meet their operational needs.

However, ATCOs also recognised that flight crews do not comply with these procedures consistently even when they are published in AIPs and are known to the airlines. One main reason could be a non-standardised symbology applied to the transponder control panels in different cockpits from different manufacturers. It is recommended to include aircraft type and/or manufacturer specific procedures in the *Pre-flight Preparation Procedures/Checklists* and in the *Aircraft Operations Manual* to further improve pilot compliancy.

Further Recommendation to A-SMGCS levels 1&2 procedures and regulations:

- c) All aircraft or vehicle 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 [32]). In order to use the A-SMGCS surveillance display safely and efficiently in all visibility conditions, all movements that intend to use the manoeuvring area should be properly equipped to be **co-operative** with an A-SMGCS in order to provide their identity on the ATCO's surveillance display.
- d) ATCOs further stated significantly that *procedures in case of an A-SMGCS failure* are not well defined so far. Such procedures or regulations have to be improved, to be matured yet, and probably better implemented.

- e) *Existing phraseology* (D135u ORD §4 [11]) can be maintained without any change when A-SMGCS is used.
- f) ATCOs further reported that A-SMGCS helps them to detect runway incursions. The two stages of alert situation are well accepted by the ATCOs. In the event of an alert being generated, the ATCO should assess the situation and should take appropriate actions without delay.

4.5 Recommendations related to visibility aspects

Several statements in the debriefing questionnaire focussed on the *visibility* conditions: ATCOs stated that A-SMGCS helps them in all visibility conditions even when visibility is not impaired. Without direct visual reference they rely on the A-SMGCS position reports and the labels with the target identification.

Problems arise in low visibility with *false targets* and the use of the conflict alerting function – as the ATCO cannot confirm the target to be false by a visual reference check. Unless false targets are kept to a minimum the A-SMGCS cannot be used in an efficient and safe way.

Visibility 3 conditions (see §5 [9]), when pilots can taxi but cannot see sufficiently to avoid collision are approximately equivalent to the conditions in which local ANSPs decide to apply low visibility procedures (LVP). Even though ATCOs would not define the exact visibility limits in terms of equivalent runway visual range (RVR), they could imagine that *longitudinal spacing* with LVP could be reduced with the use of an A-SMGCS (see debriefing results of active A-SMGCS ATCOs [26]).

4.6 Recommendations related to implementation issues

4.6.1 Cost/benefit considerations

There are no cost/benefit recommendations coming out of EMMA. The fourth layer “operational benefits” of the EMMA V&V methodology (cf. Figure 4-1) takes into account the comparison between cost savings caused by A-SMGCS operational improvements compared to all related implementation and maintenance costs. Quantities for operational improvements, like reduced taxi times or reduced load of the R/T voice communication, are provided by EMMA but the translation of the operational effects into monetary values was out of the scope of EMMA and should be done by the respective stakeholders, since they are in the better position to do so.

4.6.2 Safety assessment

The preparation of the EMMA functional hazard assessment (FHA) (cf. the EMMA FHA report D1.3.9, [13]) led to the provision of recommendations with respect to the contents of the ICAO A-SMGCS manual [31]. The EMMA FHA focuses on safety assessment in the ATM domain.

It should be realised that A-SMGCS operations can also drastically change the way of working of pilots, particularly with higher A-SMGCS implementation levels. Therefore, the EMMA “General Safety Concept” [10] describes a safety assessment plan for performing a safety assessment covering well all interactions between the ATM domain, the aircraft operations domain and the aircraft system domain. This plan also makes use of SAM as a safety assessment method for the ATM domain, and identifies some further areas in which SAM is recommended to improve.

The following safety assessment related recommendations have been derived in EMMA:

- a) The terms “system” and “equipment” should be used with more differentiation from the ICAO A-SMGCS manual [31]. For a safety analysis, it is required to define the system as a combination of physical components (i.e. equipment), procedures, and human resources organised to perform a function. This definition could also be used for the description of the operational & performance requirements in the ICAO manual.
- b) In the ICAO manual on A-SMGCS (§5.5, [31]) there is no mention of the recent EUROCONTROL work on its safety assessment methodology (SAM). With release 2, the SAM has grown more mature (even if it will continue to develop and improve) and is tailored to safety assessment in the ATM domain. However, it is recommended to mention SAM in the ICAO manual [31] as a possible way of doing safety assessment restricted to the ATM domain.
- c) With respect to the most severe hazard, it may be valuable to introduce on-board services in an early implementation step of an A-SMGCS concept.
- d) With its higher levels, A-SMGCS will drastically change the role of pilots. Hence, the ICAO manual has a broader scope than just the ‘ATM provision’ considered by ESARR4 [7] and SAM [2]. Hence, also JAR/EASA regulations concerning aircraft systems and aircraft operations are of importance (cf. also the EMMA “General Safety Concept” document [10]).

4.6.3 Training & licensing

4.6.3.1 Recommendations related to ATCOs

For already licensed ATCOs, implementation of A-SMGCS will require upgrade training. It is recommended to develop training associated with the subsequent levels of A-SMGCS implementation. For student and trainee ATCOs, the unit training plans should be amended to reflect the competence required to operate the implemented levels of A-SMGCS [12].

It is recommended to implement A-SMGCS licensing as an endorsement within ATCO ratings. Successful completion of the A-SMGCS levels 1&2 upgrade training for already licensed ATCOs should be reported to the designated licensing authority. Subsequently, and associated with a valid ADI/TWR, or ADI/GMC rating, an A-SMGCS (levels 1&2) rating endorsement should be entered in the ATCOs licence.

4.6.3.2 Recommendations related to flight crews

It is recommended with the implementation of A-SMGCS at several airports that flight crew training should include the knowledge of those A-SMGCS aspects relevant for flight crews. Flight crews should be provided with the training necessary for them to understand the system and their associated duties in terms of the introduced transponder operating procedures. It is necessary that training permits flight crews to comply with aerodrome, A-SMGCS, and ATC procedures.

In accordance with ICAO Annex 1, the Joint Aviation Authorities (JAA) have developed Joint Aviation Requirements for flight crew Licensing (JAR-FCL). For aeroplane flight crews JAR FCL – 1 is applicable [7] for training and licensing of private, commercial and airline flight crews. It is recommended that the JAA should incorporate relevant provisions in JAR FCL-1 for the use of A-SMGCS, e.g. required minimum level of theoretical and practical knowledge, training syllabi, skill test contents, and requirements considering up-to-date knowledge for the prolongation and renewal of licenses. Up to now, no specific licensing requirements have been developed with regard to A-SMGCS.

4.6.3.3 Recommendations related to vehicle drivers

It is recommended for the implementation of A-SMGCS that training should include the knowledge of those A-SMGCS aspects that are relevant for vehicle drivers active on the movement area, including the use of radiotelephony and navigation competencies. Vehicle drivers should be provided with the training necessary for them to understand their duties and to permit them to comply with aerodrome, A-SMGCS, ATC procedures.

4.7 Recommendations to the stakeholders

4.7.1 Recommendations to users

The following recommendations to users (ATCOs, pilots, and vehicle drivers) are important for the smooth implementation of A-SMGCS. They are also important to guarantee a high acceptance of the system by the users.

- a) Users should be actively involved in the entire process of A-SMGCS implementation relevant to their tasks from the first stage of project planning until operational use of the system.
- b) It is important that users specify their needs and requirements with regard to A-SMGCS and that they are directly involved in the process of system and supplier selection. Operational users have to work with the new system – they know which functions and system design would be most beneficial for their tasks.
- c) Users should familiarise themselves with the new A-SMGCS functions that affect them as early as possible and give early feedback to the system designers especially with regard to change requests or adaptations of the system functions.
- d) For a smooth system implementation it is necessary that users know the relevant system documentation and that they use the provided the necessary system training sessions to an optimum degree.
- e) All changes in procedures and responsibilities should be made available and briefed to the affected users well in advance of the system cut-over.
- f) Workload aspects should be taken into consideration. A-SMGCS may have an influence on workload, particularly on the workload of tower controllers. Controllers should give critical feedback on these issues and if necessary suggest changes with regard to responsibility and organisation of the controller positions in the tower.

4.7.2 Recommendations to A-SMGCS R&D

The reported verification and validation results (Ref. [26], [27], and [28]) contain indications about the additional R&D needed. Related to the surveillance and control functions of A-SMGCS, the main recommendations are reported below:

- a) Develop and test a standard and recommended practice (SARP) for A-SMGCS surveillance system performance verification, calibration, and approval².
- b) Investigate the optimal use of real-time tower simulation in the context of runway incursion alert development of systems and procedures. Make recommendations for a typical runway

² cf. also EUROCAE ED-87A [30], which is currently updated with this respect

incursion alerting (RIA) development and integration programme that can be used by airports and ANSPs to install an operational RIA function.

- c) Investigate the role and effectiveness of other sensors than those used in EMMA to improve the RIA function (e.g. magnetic loops, extra stop bar sensors, or electro-magnetic fences).
- d) Study the combined (runway incursion) alerting situation (both an alert facility in the cockpits and in the tower).
- e) Develop, test, and standardise methods to measure the airport (ATM and A-SMGCS-related) efficiency (minimum required parameters, testing period, conditions, etc.).

4.7.3 Recommendations to industry

- a) With the implementation of an A-SMGCS an extensive period for the adaptation (tuning) of the system should be planned, before the system can provide the expected performance.
- b) It can be advantageous for the monitoring and alerting function to be tested by local operational controllers in a simulation environment prior to the integration at the airport, in order to give a realistic impression of its operational performance and to adapt it to the users' needs.
- c) HMI design aspects are important and should be given high priority. An optimised 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.
- d) Maintenance costs of an A-SMGCS should not be underestimated.

4.7.4 Recommendations to the European Commission's policy

- a) In the light of the EMMA results, the EMMA consortium is recommending the EC to pursue close co-ordination with other international bodies (e.g. EUROCONTROL) to formulate a joint European approach in the effort to update A-SMGCS standard and regulatory documents (e.g. ICAO, EUROCAE), as well as to assure co-ordination with non-European bodies, like the Federal Aviation Agency, with the aim to approach ICAO in a co-ordinated way.
- b) SESAR, the Single European Sky implementation programme, is just starting its first phase called the Definition Phase. In March 2008, the definition phase will deliver an ATM master plan defining the content, the development, and deployment plans of the next generation of ATM systems. Therefore, the EMMA consortium is recommending the EC to support the EMMA accomplishments in order to feed the SESAR Definition Phase and more specifically the part related to future airport developments.
- c) In EMMA2, higher-level A-SMGCS services that were initially identified in the conceptual part of EMMA will be further addressed. Past experiences in developing initial A-SMGCS levels show that there definitely is a long way from R&D to implementation. Hopefully, with a solid basis of A-SMGCS surveillance and initial control functions and thanks to the EMMA and other related European projects, future development and implementation of higher level A-SMGCS services will take a quicker pace. Nevertheless, the EMMA consortium is recommending the EC to support future development of these services in the upcoming EC programmes in order to speed up operational deployment.

- d) The EMMA consortium would further recommend to the European Commission not to split extensive Integrated Projects in only two years lasting projects within one framework programme. Such a small project time compared with the high amount of contributing partners and ambitious objectives lacks efficiency in terms of reaching the project technical goals. Important phases of the E-OCVM approach or the well-proven iterative test cycle approach, which usually includes preparation, accomplishment, and evaluation of the trials, are important but they also need sufficient time. Overlaps of external project phases (project proposal phase, reporting phase) of EMMA and EMMA2 projects occurred and caused overloads of resources for the partners that were involved in both projects.

4.8 Recommendations related to a concept for higher A-SMGCS levels

The EMMA consortium conducted a study to identify a comprehensive A-SMGCS concept that allows incorporating the full scope of surveillance, control, routing and guidance services as well as new onboard-related A-SMGCS services. This concept work prepared the follow-up project, EMMA2. The concept aimed to support the stepwise implementation of a complete A-SMGCS and delivered recommendations for A-SMGCS “implementation packages” that are tailored to the user’s needs. The results were an output of several workshops with A-SMGCS users, industry, and R&D organisations.

The EMMA *implementation packages* go beyond the already existing EUROCONTROL, EUROCAE, and ICAO A-SMGCS *implementation level* definitions because they also consider equipment and procedures of each specific A-SMGCS service. The new term *packages* was chosen to distinguish the EMMA definition from the term ‘*implementation level*’. This definition of implementation levels proved to be insufficient in meeting the needs of stakeholders during a stepwise implementation of a full scope A-SMGCS.

EUROCONTROL’s and EUROCAE’s definition with its four implementation levels focuses on the main four A-SMGCS functions: *surveillance*, *control*, *guidance*, and *routing*, which works fine with *surveillance* and *control* because these two functions depend on each other logically in a successive way and do not consider the onboard part, except for the transponder. Moreover, these two services are mainly used to assist the users, thus procedures do not have to be changed fundamentally, and interoperability to other services is not a critical issue.

The implementation of automated routing or guidance services, however, would increase the complexity of the A-SMGCS and their operational use still lacks maturity. A concept for those higher levels has to give careful consideration to changing operational procedures, shifting responsibilities from human to equipment (e.g. visual reference vs. electronic display), introducing automated onboard services and equipments, as well as to the interrelations between the A-SMGCS functions.

Current level 3 and level 4 concepts do not help here anymore as they do not adequately address the full scope of A-SMGCS operational use. ICAO considers the responsibility shift between controllers, pilots, and equipment for all A-SMGCS services, which must be seen as a first step, but does not give sufficient information on procedures with which the system is used nor does it describe what technical enablers would be needed and what service performance level the users can expect.

EMMA implementation steps for A-SMGCS services

The EMMA operational concept approach started with extending the EUROCONTROL levels 1&2 concept [5] [6] with a detailed description of all A-SMGCS services that includes guidance, routing, planning, and on-board services, as well as an extension of surveillance and control services. This was done for each of the three main users of an A-SMGCS: air traffic controllers (ATCO), flight crews, and vehicle drivers.

The second step was to look for appropriate technical enablers that are needed to bring the service to life.

The third step was to give recommendations for successive implementation steps for each A-SMGCS service. Table 4-1 depicts the arrangement of implementation steps for each A-SMGCS service in the recommended order. The services are attributed to the main users – ATCO, pilots, and vehicle drivers – and aligned with a timeline (cf. also EMMA OSED document, §2, [9]).

		Expected Implementation Steps						
ATCO	Surveillance	S1 aircraft and vehicles in the manoeuvring area		S2 S1 + aircraft in apron areas			S3 S2 + vehicles in apron area	
	Control		C1 Conflicts on RWYs	C2 Conflicts TWY	C3 CPDLC (electronic flight plan management, clearance management)		C4 Conflicts on Aprons	
	Guidance	G1 Manual switched ground guidance				G2 Auto switch		
	Routing		R1 Manual Routing	R2 Semi-auto Routing	R3 Auto Routing (incl. Planning)	R4 DMAN / ROP		
Flight Crew	Aircraft		A1 Electronic Moving Map		A2 EMM with Ground traffic + CPDLC		A3 HUD	A4 Auto steering
Vehicle Driver	Vehicle	V1 Electronic Moving Map		V2 EMM with Ground Traffic	V3 CPDLC			
Timeline		→ (t)						
ROP	Runway Occupancy Planning							
EMM	Electronic Airport Moving Map							
HUD	Head-Up Display							
S1	Surveillance Service for ATCOs step 1							
C1	Control Service for ATCOs step 1							
G1	Ground guidance means Service for ATCOs step 1							
R1	Routing Service for ATCOs step 1							
A1	Onboard Services for flight crews step 1							
V1	Onboard Service for Vehicle Drivers step 1							

Table 4-1: A-SMGCS services and implementation steps

From implementation steps to implementation packages

Having defined evolutionary implementation steps for each A-SMGCS service the users can cluster them into *implementation packages* (IPs), which exactly meet their operational needs at the airport. To support this process EMMA recommended special implementation packages in accordance to the airport needs, considering the airport complexity, traffic volume, and prevailing visibility conditions (cf. §5, OSED, [9]).

Implementation of innovative systems at airports is driven by a number of factors, amongst which is the budget to be spent, political pressure, and image. Numerous innovative systems have been site-accepted and never used due to lack of consistency with the other tools and the environment, lack of procedures and training, or inadequate performance to the real needs. However, for the situations in which operational needs for an A-SMGCS are the main driving factor for its implementation, the implementation packages defined in EMMA (cf. [9]) are recommended so as to build up an acceptable equilibrium between equipment, procedures, and interoperability with adjacent systems.

5 Remaining open issues

5.1 Issues related to A-SMGCS surveillance

The EMMA project found evidence that the A-SMGCS Surveillance service has reached a very high maturity. Today it provides full benefits to the ATC community in the operational environment. Hence only a few open issues remain with regard to improving this service. Nevertheless, the EMMA consortium wants to highlight a crucial element for the successful operational use of A-SMGCS: **Compliance to Transponder Operating Procedures**. During EMMA V&V activities, it has been recognised that flight crews do not comply with these procedures consistently even when they are published in AIPs and are known to the airlines. This issue is a key element for the adequate operation of A-SMGCS on airports and has to be solved.

To a lesser degree, an issue has been identified related to the use of the A-SMGCS surveillance service in visibility 3 conditions, when controllers cannot see outside and when pilots cannot apply “see and be seen”. Controllers’ opinions indicate that *longitudinal spacing* in low visibility operations could be reduced with the use of A-SMGCS. This idea introduces a definition of *separation* on the ground, which does not exist at the moment, as well as a definition of associated procedures to operate in VIS-3 conditions to maintain the separation minima.

5.2 Issues related to A-SMGCS control

The A-SMGCS control service and, more specifically, the *monitoring and alerting function* have not reached a level of maturity that permits full operational use at the EMMA airports. For the time being, only basic conflict alerting algorithms, like automatic alerts with aircraft or vehicle movements crossing a lit stop bar, are implemented and operational at Prague-Ruzyně. However, real-time simulations and live flight tests, which were used in EMMA to evoke more complex conflict situations (e.g. arrival-arrival conflicts with crossing runways), show very promising results regarding controllers’ acceptance. Solutions to allow a more developed monitoring and alerting function implementation should be investigated in further research activities.

6 Annex I

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6.2 Acronyms and Abbreviations

Abbreviation	Meaning
ADI/GMC	Aerodrome Control Instrument/ Ground Movement Control
ADI/TWR	Aerodrome Control Instrument/ Tower
ADS-B	Automatic Dependant Surveillance – Broadcast
AIP	Aeronautical Information Publication
ANS CR	Air Navigation Services Czech Republic
ANSP	Air Navigation Services Providers
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
AUEB	Athens University of Economics and Business

Abbreviation	Meaning
BETA	operational Benefit Evaluation by Testing an A-SMGCS
CPDLC	Controller Pilot Data Link Communication
DEFAMM	Demonstration Facilities for Airport Movement guidance control and Management
DSNA	Direction des Services de la Navigation Aérienne (French Air Navigation Services)
EASA	European Aviation Safety Agency
EMM	Electronic Moving Map
ENAV	Italian Company for Air Navigation Services
E-OCVM	European Operational Concept Validation Methodology
ESARR	EUROCONTROL Safety Regulatory Requirement
ETG	EuroTelematik AG
FCL	Flight Crew Licensing
FHA	Functional Hazard Assessment
GND	Ground
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
JAA	Joint Aviation Authority
JAR	Joint Aviation Requirement
LVO	Low Visibility Operation
LVP	Low Visibility Procedures
MAEVA	Master ATM European Validation Plan
NOTAM	Notice To Airman
OSD	Operational Service And Environmental Description (EMMA)
RTS	Real-Time Simulation
RVR	Runway Visual Range
SAM	Safety Assessment Methodology
SMR	Surface Movement Radar
TATM	Thales ATM
THAV	Thales Avionics
TREN	Transport and Energy
TUD	Technische Universitaet Darmstadt
TWR	Tower
TWY	Taxiway
V&V	Verification and Validation
VGH	Validation Guideline Handbook