A-SMGCS VERIFICATION AND VALIDATION RESULTS FROM THE PROJECT EMMA (LEVEL 1&2)

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Abstract

A-SMGCS is a modular system defined in the ICAO Manual on Advanced Surface Movement Guidance and Control Systems (A-SMGCS) [8]. Such systems aim to "*maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety*" [8]. With the complete concept of an A-SMGCS, air traffic controllers (ATCO), flight crews, and vehicle drivers are assisted with surface operations in terms of surveillance, control, routing/planning and guidance tasks. To harmonise the implementation of the first two levels of A-SMGCS, which focus on surveillance and conflict monitoring, and to further mature the necessary technology and operating procedures, the European Commission funded the project EMMA (European airport Movement Management by A-SMGCS) within the sixth framework programme. Within EMMA, A-SMGCS level 1&2 systems were installed at three European mid-size airports: Milan-Malpensa, Prague-Ruzyně, and Toulouse-Blagnac. Technical and operational trials were conducted at all three sites to verify the technical performance against the requirements and to prove operational feasibility. Additionally, real-time simulations were performed in order to tune parameters of the monitoring and alerting function and to also assess operational improvements under experimental conditions. This paper presents the EMMA validation approach, the main findings and results as well as lessons learnt of the first project phase (2004-2006).

Introduction

Following the EUROCONTROL Performance Review Report of 2005 [5] airport delays are a growing proportion of the total ATM delays. Nearly all European hubs and already some mid-size airports are on the list of the 15 most penalising airports in Europe, which together generate 77% of all airport ATFM delays.

Extending existing airport infrastructure, e.g. by building new runways, is a very difficult and complex process associated with many restrictions. Therefore, the optimal usage of existing infrastructure more and more becomes a necessity. Despite the importance of optimal resource usage, flight deck operations on the ground are still not very sophisticated nowadays. Implementation of modern cockpit technology for surface operations lags behind the developments for other flight phases. "Seen and be seen" is still the most common practice on ground. After landing pilots have to navigate using paper maps and look out of the window to avoid other traffic. Above that ATCOs are performing the surveillance task mainly visually. Frequently, ATCOs are supported by surface movement radar (SMR) only giving them poor analogue radar plots with a lot of clutter and nuisance targets. As soon as the visual reference is impaired all surface operations are severely impacted by an increasing workload and a decreasing situation awareness of all participants, compromising safety and airport capacity and increasing delays. This leads to negative consequences for the approach areas and finally to unfavourable network effects in the overall air transport system.

An A-SMGCS helps to overcome this poor situation. In its basic level 1 it provides the ATCOs with a display showing the complete traffic situation that includes the position of all aircraft and vehicle movements and their identification. Since it is assumed that each day in the US and Europe at least one runway incursion is occurring, which may lead to severe accidents, such as the Milan-Linate accident in 2001, in its level 2 the A-SMGCS provides the ATCO with an automatic runway incursion monitoring and alerting function.

EMMA Project Background

The EMMA integrated project is divided into two project phases, which are called **EMMA** (2004-2006) & **EMMA2** (2006 - 2009), and is set within the Sixth Framework Programme of the European Commission Directorate General for Energy and Transport (DG-TREN). It looks at A-SMGCS as a holistic approach for changes in airport operations. It builds on the experiences of earlier projects such as 'Operational Benefit Evaluation by Testing A-SMGCS' (BETA) [11]. With BETA new technologies for data extraction, digitising, data fusion, data link and multilateration became available. Although A-SMGCS progressed from a demonstration status to a semi-operational system, the complete proof of benefit of A-SMGCS was missing. Therefore, EMMA was launched to set the standards for A-SMGCS systems and their operational usage, safety and interoperability while also focussing on the benefit expectations.

A-SMGCS Services (level 1&2)

A complete A-SMGCS as described in [8] supports tower controllers, apron/ramp controllers, pilots, and vehicle drivers in an all-embracing manner with the following four functions: surveillance, control, routing/planning, and guidance. EMMA validation activities in their first project phase (2004 – 2006) focussed on the first two implementation levels, which correspond to a surveillance service and a runway safety net. These services currently have the highest level of maturity:

Surveillance (level 1)

Each individual aircraft is seamlessly tracked and identified from final approach until it reaches the parking position and, vice versa, from the gate or stand until leaving the CTR.

Runway monitoring and alerting function (level 2)

The level 2 implementation looks at an automated control service that helps controllers to detect potentially dangerous conflicts on runways and restricted area intrusions. The clear advantage of this approach is that it is pro-active and not re-active. Preventing conflicts before they get imminent is obviously better than solving them under time pressure when they become obvious.

Test Sites, Architecture and Operations

A level 1&2 A-SMGCS system was installed at three European mid-size airports: Milan-Malpensa, Toulouse-Blagnac, and Prague-Ruzyně (cf. Figure 1). With Milan and Toulouse operational shadow-mode trials were performed, whereas the ATCOs in Prague could even use the system within their regular working environment. Controllers were trained and certified to use the system fully operational.

Multi sensor systems integrating ASR, SMR, MLAT, ADS-B, and special gap-fillers were installed and tuned at all sites. Figure 2 represents the general system architecture of a level 1&2 A-SMGCS.

A-SMGCS traffic situation displays (TSD) showing the complete traffic situation were installed at each controller working position. The ATCOs in Prague could use the TSD as a primary means for identification in all visibility conditions (A-SMGCS level 1). Furthermore, the

Figure 1: Milan-Malpensa, Toulouse-Blagnac, and Prague Ruzyně from the bird's perspective

monitoring and conflict alerting function (A-SMGCS level 2) informed the ATCO in case of conflict situations like 'stop bar crossings', 'infringement of restricted areas', or 'runway incursion'.

However, the role of the ATCO has not really to be changed with the implementation of an A-SMGCS level 1&2. The new source of surveillance information and conflict monitoring will complement the usual source for surveying the traffic. It is expected that the ATCOs' situation awareness improves, which will be followed by an increase of safety and a more efficient control of the traffic. For instance, pilots' position reports are no longer necessary, which reduces the load of the voice channel and taxi times will be reduced due to a better situation awareness of the ATCO.

In addition to the operational field trials, real-time simulation trials were conducted with Milan-Malpensa and Prague ATCOs. This was necessary for tuning parameters of the 'situation monitoring and conflict alerting' function to the ATCOs' needs and also assessing A-SMGCS level 1&2 operational improvements under real experimental conditions.

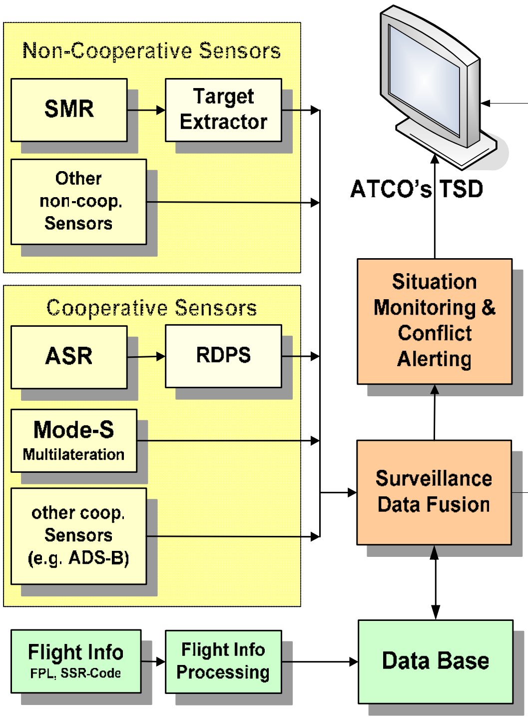

Figure 2: General system architecture of a level 1&2 A-SMGCS

EMMA Verification & Validation Methodology testing an A-SMGCS

The basic aim of the EMMA project was the verification and validation (V&V) of A-SMGCS (level 1&2) functionality as described in the ICAO Manual [8] and further refined in the Operational Requirements Document (ORD) of EMMA [3], which bases on the technical and operational functionality outlined in the official documents of the EUROCONTROL A-SMGCS project [1], [2].

Before successful V&V takes place, verification, i.e. testing against system specifications should occur. Only if verification results in an A-SMGCS that performs at the required level, successful validation of the concept can be started.

- **Verification** is testing against predefined technical requirements, ('did we build the system right?').
- **Validation** is testing against operational requirements ('did we build the right system?').

With EMMA V&V was split into four sub-stages [15]. These are illustrated in the figure below.

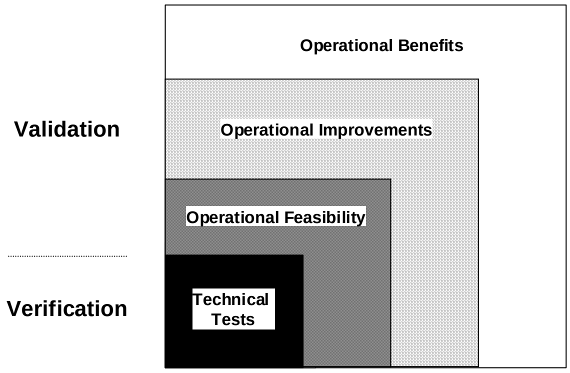

Figure 3: Stages of EMMA V&V activities

The **Technical Tests** stage refers to the tests that must be conducted in order to assess the technical performance of A-SMGCS equipment. This stage answers the question: "What are the performances of the equipment?"

The **Operational Feasibility** stage refers to the definition of the operational use of equipment and procedures, in accordance with the performances assessed in the previous stage. It answers the question: "Given the performances of the equipment, is it usable and acceptable?"

The **Operational Improvements** stage refers to evidence of the operational improvements, in terms of safety, capacity, efficiency, and human factors, using the equipment and the procedures defined in the previous stage. It answers the question: "Given the accepted A-SMGCS equipment and procedures, how is ATM performance improved?"

The **Operational Benefits** stage refers to the translation of operational improvements into terms of economical benefits. It answers the question: "What are the economic benefits for the purchasers and users of A-SMGCS products?". This translation of operational effects into monetary values was out of the scope of EMMA and should be carried out by the respective stakeholders, since they are in a better position to do so.

In general, it was expected that the validation exercises will demonstrate the operational feasibility of the A-SMGCS operational concept and that the concept provides a solution to the specific ATM problem and leads to operational improvements when comparing it to current SMGCS.

Test Platforms

Real-time simulations (RTS) in EMMA focussed on the operational feasibility of the 'monitoring and alerting' function. The simulation test platforms were used to evoke safety critical events and to tune the system alerts to the needs of the ATCOs. In addition, overall operational improvements in terms of safety and efficiency gains were to be proven with an RTS platform.

On-site, V&V activities concentrated on the measurement of the technical performance by using test cars and/or automatic performance assessment tools. Operational feasibility of the whole system was subject of investigations with participation of the end users. Measuring operational improvements in the field, however, is very difficult or even impossible. Frequently, both users of the system and the system itself are not certified for full operational use. Furthermore, a valid baseline with ceteris paribus condition compared to the experimental condition (with A-SMGCS) does not exist. Weather, traffic mix, traffic amount or the runway in use change frequently and cannot easily be controlled. Any effects of an operational improvement are then overshadowed. However, if field trials show that the overall system meets the technical performance and is operationally feasible, then operational improvements, which are measured in the RTS, can be transferred to the real environment.

Results

The results are presented in accordance with the following main categories in the EMMA V&V methodology:

- Technical Tests,
- Operational Feasibility, and
- Operational Improvements.

Toulouse-Blagnac and Milan-Malpensa evaluated the A-SMGCS in on-site shadow-mode trials, which revealed important feedback to the technical and operational performance. Prague Ruzyně already started implementing an A-SMGCS within the BETA project, so that implementation and tuning of the system could start from a more matured level in EMMA. During the EMMA project Prague achieved the breakthrough to use the A-SMGCS fully operational under all visibility conditions. At the time of the validation activities, Prague controllers had already used the A-SMGCS for more than seven months and thus could give very detailed feedback regarding its operational feasibility and operational improvements. Therefore, validation results described in this paper mainly concentrate on results obtained at Prague Airport.

Technical tests

At the three test site airports the most important technical performance requirements of the surveillance and conflict detection function were assessed with the help of 18 verification indicators (see Table 1). These indicators were derived from the EMMA technical and operational requirement documents [6] [3], which again were based on the A-SMGCS ICAO Manual [8] and the EUROCAE ED-87A [4].

The verification tests aimed at assessing the performance requirements by short- and long-term observations. **Long-term** measurements were performed by the recording and analysis tool MOGADOR, which was developed within EMMA (as described in [13]). The MOGADOR tool is a new verification tool, which fully automatically analyses specific surveillance performance parameters from a long-term recorded data pool of regular airport traffic. This tool revealed interesting results that can also be used to tune and adapt the A-SMGCS to meet the operational performance needs. However, long-term results analysed with MOGADOR lacked maturity because time was not sufficient to fully adapt the MOGADOR algorithm to the specific test airport characteristics, which would be necessary to automatically measure the real system performance.

Prior to the long-term assessment, technical **short-term** tests were performed in order to assess the readiness of the A-SMGCS system and to verify the system's compliance with the technical requirements (EMMA TRD [6]) by visual observation. Short-term test procedures leaned on EUROCAE [4] but were also adapted and improved within EMMA. They mainly make use of properly equipped test cars or test aircraft, knowing their own position on the aerodrome surface, which then is compared with the position assessed by the ground system.

In Table 1 short- and long-term results of the technical performance tests carried out at Prague Airport are compared with the respective requirements.[1]

ID	Indicator	Acro-nym	Require ment	Measured Value	
				Short-Term	Long-Term
VE-1	Coverage Volume	CV	Approach Manoeuv. area Apron	√ √ √	n.a.
VE-2	Probability of Detection	PD	≥ 99.9%	99.7%	97,1 – 99,4%

[1] For the technical results of the other sites and decisions about all other technical requirements the interested reader is referred to the EMMA *V&V Analysis Report* [16].

ID	Indicator	Acro-nym	Require ment	Measured Value	
				Short-Term	Long-Term
VE-3	Probability of False Detection	PFD	< 10E-3 per Reported Target	0.07%	0,04 – 0,16%
VE-4	Reference Point	RP	Not defined	2-20 m	n.a.
VE-5	Reported Position Accuracy	RPA	≤ 7.5 m at a conf. level of 95%	3.2 m (static)	n.a.
VE-6	Reported Position Resolution	RPR	≤ 1 m	0.1 m	n.a.
VE-7	Reported Position Discrimi-nation	RPD	Not defined	Not tested	n.a.
VE-8	Reported Velocity Accuracy	RVA	Speed: ≤5m/s Direction: ≤10° at 95% conf.	1.2 m/s 7.9°	n.a.
VE-9	Probability of Identifi-cation	PID	≥ 99.9% for identifiable targets	99.7%	78,8 – 94,1%
VE-10	Probability of False Identifi-cation	PFID	< 10E-3 per Reported Target	0.00%	3,2 – 19,7%
VE-11	Target Report Update Rate	TRUR	≤ 1 s	0.47s	n.a.
VE-12	Probability of Detection of an Alert Situation	PDAS	≥ 99.9%	100%	n.a.
VE-13	Probability of False Alert	PFA	< 10E-3 per Alert	Insufficient data	n.a.
VE-14	Alert Response Time	ART	≤ 0.5 s	<0.5 s	n.a.
VE-15	Routing Process Time	RPT	≤ 10 s	n.a.	n.a.
VE-16	Probability of Conti-nuous Track	PCT	Not specified	n.a.	See [9] §2.3.16
VE-17	Matrix of Detection	MOD	Not specified	n.a.	See [9] §2.3.17
VE-18	Matrix of Identifi-cation	MOI	Not specified	n.a.	See [9] §2.3.18

Table 1: Summery of Technical Verification Results (PRG)

All main technical requirements could be verified (cf. EMMA V&V Analysis Report [16]) but also performance lacks were revealed. These lacks could either be overcome by a technical tuning of the system or simply showed the physical limits of the current technique. In some cases, when the user accepted a lower performance, they showed the inadequateness of the requirement. For example, VE-2 'Probability of Detection' should be 99.9% but only 99.7% was reached in Prague. Nevertheless, controllers' acceptance of this lower level of performance finally led to the verification of the parameter.

Operational feasibility

The operational feasibility tests aimed at assessing the ATCOs' acceptance of the EMMA operational procedures and requirements. It was expected that the operational feasibility of the system would be confirmed under all visibility conditions by using the procedures defined in the EMMA ORD [3]. The operational feasibility was assessed in RTS and on-site through intensive debriefing sessions with the ATCOs using specially prepared questionnaires.

Real-time simulations

In the Prague simulations a total of 11 ATCOS in four groups participated in the RTS trials. Three traffic scenarios were generated in accordance with the three different visibility conditions (VIS1, VIS2, and VIS3), (cf. Table 2).

	Scenario A	Scenario B	Scenario C
RWY QFU	↑24 ↓31	↑06 ↓13	↑24 ↓24
Approach	ILS CAT I	VOR/DME	ILS CAT II/III
Weather conditions	VIS2 Day Wind 350/10 2km visibility	VIS1 Day Wind 130/15 5km visibility	VIS3 Day Wind 350/10 VRB/2 RVR 400m visib.
Movements	~ 35 / h	~ 41/ h	~ 25 / h

Table 2: Traffic Scenarios with Prague RTS

Each of the 11 ANS-CR ATCOs was given a 30-item acceptance questionnaire after finishing all test runs. The Questionnaire mainly addressed the use of the A-SMGCS HMI and new procedures, but also included items to the performance of the runway monitoring and alerting function. The answering scale reached from 1 “strongly disagree” to 10 “strongly agree”. Except for two items all statements were answered towards the expected end of the scale and a t-test with an error probability of $\alpha = 0.05$ proved their significance[2]. Therefore, it can be stated that the use of the A-SMGCS HMI and the performance of automatic alerts were of high operational feasibility in the Prague RTS.

Supplementing the Prague RTS by a second airport environment, another industrial system solution, with ENAV ATCOs as subjects, a second series of RTS for the Milan-Malpensa environment were performed at the NARSIM-Tower simulator of NLR in Amsterdam. The experiments also focussed on verifying technical performance and evaluating operational improvements related to the integration of a monitoring and alerting system into the current operational environment (baseline scenario). The ad hoc validation plan described both nominal and non-nominal validation sessions. The experiment scenarios discerned three major conditions: Medium or high-level traffic volumes, under different visibility conditions (VIS-1 and VIS-2), and with or without support of an A-SMGCS. Feasibility checks with ENAV controllers in RTS had to confirm the pre-configured system parameters and indicate unexpected behaviour of the tool or malfunctions in order to ensure that the installed system was fit for more performance-oriented validation activities.

Field trials

During the EMMA operational field trials in Prague a total of 15 ANS-CR ATCOs filled in the debriefing questionnaire. All 15 ATCOs had worked with the A-SMGCS for more than seven months at the time of the interviews. A debriefing questionnaire with 144 items was handed out after their regular shift. 98 of the 144 items referred to the “operational feasibility” questions/statements, which were segregated into five areas:

- General usability
- Surveillance service
- Control service
- HMI design
- Procedures

The items could be answered on a scale from 1 (disagreement) to 6 (agreement). One-sample t-tests with an expected mean value of 3.5 and an error probability of $\alpha = 0.05$ were applied to prove statistical significance for all items.

[2] The complete results can be found in the Prague Test Report D6.3.1 [9].

The results revealed that the controllers accepted the A-SMGCS and thus approved its “operational feasibility”. The following items are typical examples of the 98 ‘feasibility’ items that were given to the ATCOs (all results to be found in [9]):

- **VA-03 Surveillance:** “*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.*” (Mean (M) = 5.4; p = 0.00*[3]), or
- **VA-16 Surveillance:** “*I think that the A-SMGCS surveillance display could be used to determine that an aircraft has vacated the runway.*” (M = 5.3; p = 0.00*), or
- **VA-79 Control:** “*The information displayed in the A-SMGCS is helpful for avoiding conflicts.*” (M = 5.1; p = 0.00*), or
- **VA-75 HMI:** “*The A-SMGCS provides the right information at the right time.*” (M = 5.1; p = 0.00*), or
- **VA-55 Procedures:** “*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.*” (M = 5.3; p = 0.00*)

In total 77 of the 98 items proved their significance in the expected direction. Most of the non-significant VA ‘feasibility’ items referred to the monitoring and alerting function whereas the ATCOs could not use the full scope of this service yet but only the “stop bar crossing” alerts as a first step. However, additional case studies with flying test aircraft, which were used to evoke additional conflict situations (e.g. arrival-arrival conflicts with crossing runway), showed that also the performance of other conflict situation alerts was highly accepted by the controllers during the field trials.

Operational improvements

Real-time simulations

With EMMA, high-level and low-level V&V objectives were formulated and translated into measurable indicators. Table 3 gives an overview of the operational improvements that were intended to be measured with real-time simulation exercises. The ATCOs worked alternately with A-SMGCS and with their current SMGCS, which served as the baseline condition. By comparison of those two test conditions, operational improvements of the A-SMGCS could be assessed.

[3] A star (*) signals statistical significance with $p < 0.05$.

High-level Objective	Low-level Objective	Indicator
Safety	Reduced number of incidents and accidents	Number of incidents and accidents
	Faster identification and mitigation of safety hazards	Time for conflict detection, identification, and resolution
Efficiency/ Capacity	Lower Taxi Time for in and outbound traffic	Taxi Time
	Lower duration of radio com	Duration of radio communications (R/T load)
Human Factors	Higher Situation Awareness	Situational Awareness
	Convenient level of workload	Workload

Table 3: Measurements in RTS

In the following the most interesting results are reported in accordance to the abovementioned indicators (cf. Table 3):

Number of incidents and accidents

No accidents were observed during the RTS trials. Incidents occurred but they were caused by the pseudo-pilots and thus were not human errors in terms of ATCO mistakes. In general, natural ATCO errors are very rare and thus hard to assess in test trials.

Time for conflict detection, identification, and resolution

The reaction time was assessed by an observer who measured the time between the initiation of a conflict and the reaction of the ATCO in charge. The reaction of an ATCO was defined by the time when the ATCO contacts the pilots to resolve the conflict. Pilots in the simulation were not real pilots but pseudo-pilots. They were instructed to cause conflict situations.

Prague RTS results showed an improvement of 11.5% in the 'reaction time' of the Tower Executive Controller (TEC) between A-SMGCS and the baseline condition even if statistical significance ($M = -0.69$ seconds, $T_{(12)} = -0.560$, $p > 0.05$) could not be achieved. However, an important trend was discovered that showed that ATCOs react faster in the A-SMGCS condition (cf. Figure 4).

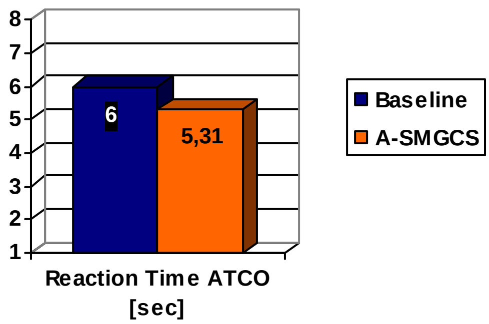

Figure 4: ATCO's reaction time in case of conflict situations

Taxi Time

The taxi time was measured automatically for each aircraft starting from the gate (velocity > 0 kts) until the wheels left the ground (take-off) for outbound movements. For inbound movements the time measurement started when the wheels touched the ground (touch down) until the velocity was 0 at the gate or stand. Since identical traffic scenarios were used for A-SMGCS and baseline trials[4], pairs of identical taxiing aircraft within identical traffic scenarios could be generated. This procedure guaranteed that measured taxi time differences could be attributed to better efficiency of A-SMGCS.

With Prague RTS, pairs of "taxi times" were summed up for each scenario A, B, and C and separated in A-SMGCS and baseline condition. The results showed significant differences in the taxi times between A-SMGCS and the baseline condition: $M_{Total} = -30$ seconds, $T_{(178)} = 1.973$, $p < .05$. This mean value corresponds to an effect of 5.5%.

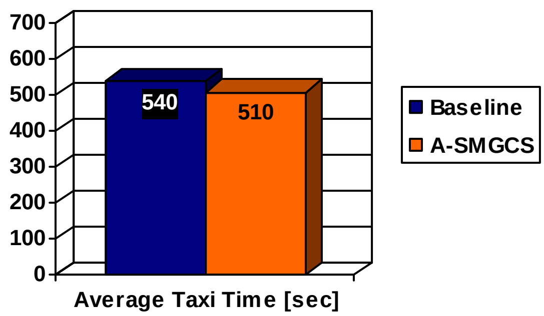

Figure 5: Average taxi times

Since the aircraft, controlled by pseudo-pilots, always have a constant speed level, those taxi time differences can only be interpreted as being caused by a more efficient control by the ATCOs using A-SMGCS. The detailed results also revealed that the

[4] with the exception that call signs were changed to alleviate recall effects with controllers

taxi time effect is particularly high with scenario B (nearly 18%) where visibility is good but the amount of traffic is the largest. Finally, it must be stated: Yes, A-SMGCS reduces taxi times.

Duration of radio communications

The duration of radio communication was measured for each controller working position, Tower planning-, Tower executive-, and ground executive controller (TPC, TEC, and GEC). The durations refer to 3600 seconds overall test time. Figure 6 outlines the respective results.

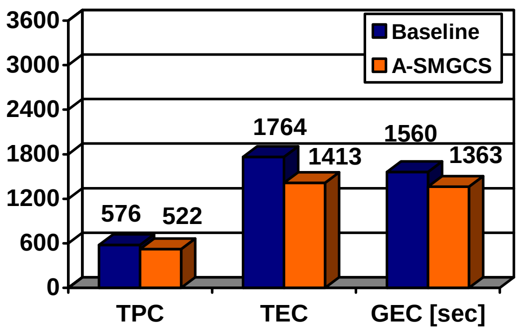

Figure 6: Duration of radio communication for three controller working positions

A two-way 2x3 ANOVA showed a difference of 162 seconds between A-SMGCS and baseline, which revealed a positive trend but did not become significant ($F_{(1, 30)} = 3.6$, $p > 0.05$). However, a p-value of 0.06 is rather close to significance and with a greater sample size the effect should be proven.

Situation awareness (SA)

After each test run the ATCO's situation awareness was measured with the SASHA questionnaire. The questionnaire uses a five-point scale and contains 12 questions, of which the last one addresses SA globally: "*How would you rate your overall situation awareness during this exercise?*" All ratings were merged into two scores per controller, one for the A-SMGCS and one for the baseline condition (cf. Figure 7).

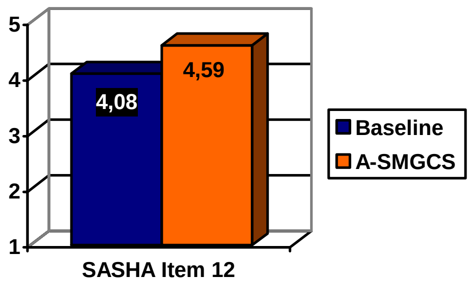

Figure 7: ATCOs' Situation Awareness

A t-test with repeated measurements showed the significance of this expected result ($T_{(10)} = 3.0$, $p < 0.05$): Yes, A-SMGCS increases the ATCOs situation awareness.

Workload

In every test run each ATCO was asked to indicate the perceived workload rating every 10 minutes. The controller could choose one of five categories: *underutilised, relaxed, comfortable, high, or excessive*. The mean values were analysed in a 2x3 (A-SMGCS x Scenario) ANOVA with repeated measurements on all independent factors. The ANOVA revealed no significant main effect of A-SMGCS ($F_{(1,10)} = 0.019$; $p = 0.89$) with a mean of $M = 2.285$ compared to the baseline mean of $M = 2.276$ on a scale reaching from 1 to 5. Most of the time the controllers felt *relaxed* and *comfortable* in the simulation runs, notwithstanding the test condition A-SMGCS or baseline. Traffic scenarios were not demanding enough to put stress on the controllers, not even in the baseline condition. Therefore, A-SMGCS had no chance of showing a workload reduction.

Field Trials

Because of the laboratory conditions of a simulation platform, operational improvements were mainly assessed there. Nevertheless operational improvements could also be deduced from interviews with active ATCOs after their regular shifts using an A-SMGCS. The Prague ATCOs were asked to estimate their perceived safety and efficiency when they worked with A-SMGCS compared to earlier times when they could not use the new system. As already outlined above, a questionnaire containing 144 items was handed out to the ATCOs. 46 items referred to operational improvements in terms of safety, efficiency, and human factors.

In the following, an excerpt of the most interesting answers to the 46 items is given[5]. The answering scale reached from 1 (disagreement) to 6 (agreement) and one-sample t-tests with an expected mean value of 3.5 and an error probability of $\alpha = 0.05$ were applied to prove statistical significance for all items:

- **VA-28 Safety:** "*When procedures for LVO are put into action, A-SMGCS helps me to operate safer.*" (M = 5.4; p = 0.00*), or
- **VA-62 Safety:** "*I think A-SMGCS can help me to detect or prevent runway incursions.*" (M = 5.0; p = 0.00*), or
- **VA-09 Efficiency:** "*When visual reference is not possible, I think identifying an aircraft or vehicle is more*

[5] For the complete results, please have a look at the EMMA V&V Analysis report [16].

efficient when using the surveillance display." (M = 5.2; p = 0.00*), or

- **VA-10 Efficiency:** "*I think, also in good visibility conditions, identifying an aircraft or vehicle is even more efficient when using the surveillance display.*" (M = 5.2; p = 0.00*), or
- **VA-28 Efficiency:** "The A-SMGCS enables me to execute my tasks more efficiently."
(M = 5.4; p = 0.00*), or
- **VA-28 Efficiency:** "*The number of position reports will be reduced when using*
A-SMGCS (e.g. aircraft vacating runway-in-use." (M = 5.4; p = 0.00*), or
- **VA-124 Efficiency:** "*The A-SMGCS enables me to handle more traffic when visual reference is not possible.*" (M = 4.5; p = 0.00*), or
- **VA-12 Human Factors:** "*The A-SMGCS display gives me a better situational awareness.*"
(M = 5.4; p = 0.00*), or
- **VA-59 Safety:** "*When procedures for LVO are put into action, A-SMGCS helps me to reduce my workload.*" (M = 5.2; p = 0.00*).

In total 38 of the 46 items proved their significance in the expected direction. The eight non-significant items mainly related to ambitious capacity effects, where the ATCOs could not imagine that an A-SMGCS level 1&2 system could already solve those problems. However, the majority of the answers further support the hypothesis that A-SMGCS provides significant operational improvements that will result in operational benefits for all stakeholders of an A-SMGCS.

Transition of Results in detailed Recommendations

The following summarising statements contain the most important recommendations obtained from the EMMA V&V activities (cf. also the EMMA Recommendation Report [10]):

- It was proven that the ATCOs can use the A-SMGCS surveillance display as a primary means for identification, as it provides an identification label for every Mode-S[6] equipped aircraft.

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

- It is recognised that flight crews do not comply with the transponder operating procedures consistently even when they are published by AIS and are known to the airlines. It is recommended to include type specific procedures in the pre-flight preparation procedures/checklists and in the aircraft operations manual to further improve pilots' compliancy.

- The use of a standardised and well proven validation approach is required for achieving reliable and robust V&V results. The use of the MAEVA VGH [14] with its stepped evaluation view within EMMA V&V contributed substantially to the production of reliable validation results. In future validation projects, the European Operational Concept Validation Methodology (E-OCVM, [12]) should be consulted as well.

- The tuning of a runway monitoring and alerting function in simulation before running it operationally is a compulsory step to assure its operational feasibility in terms of safety and efficiency.

- 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 calls for continuous long-term observation over a period of several weeks. Automatic assessment tools, like MOGADOR, may help here.

- Due to a high number of site specificities extensive tuning is a compulsory step to obtain a sufficient and reliable system performance.

- In order to use the surveillance display safely and efficiently in all visibility conditions, all aircraft and vehicle movements, that intend to get authorised to use the manoeuvring area, should be properly equipped to be co-operative to an A-SMGCS in order to provide their identity on the ATCO's surveillance display.

Conclusion and Outlook

EMMA phase 1 (2004 – 2006) was a project, which was founded to set the last bricks in the wall of a validated and consolidated A-SMGCS level 1&2 concept for support of harmonised, worldwide implementation. This effort was performed in close co-ordination with EUROCONTROL's A-SMGCS project being based on a common level 1&2 concept. Within EMMA, level 1&2 systems were implemented at three European mid-size airports to perform extensive trials leading to meaningful results, which should further support, improve, and finally validate the existing concept. The authors of this paper did not attempt to fully cover all facets of the EMMA activities but they tried to provide an overview of the EMMA strategy and the most meaningful project results.

At three test sites the system performance was measured and verified against ICAO [8] requirements. System performance and new procedures were assessed for their operational feasibility and their effects on operational improvements. Finally, all results yielded feedback for ICAO requirements (see EMMA V&V analysis report [16] for the complete feedback).

The mentioned results regarding operational feasibility and improvements were obtained in real-time simulations and field trials. Simulation experiments proved the feasibility of new procedures, the A-SMGCS HMI, and the runway monitoring and alerting function. They showed operational improvements in terms of a lower duration of radio communication, a faster ATCO reaction time in case of conflict situations, an improved situation awareness of the ATCOs, and a significant reduction of the average taxi times by 5,5%. In field trials, standardised interviews with active ATCOs using the A-SMGCS at Prague airport confirmed the operational improvements.

Those improvements with more efficient and safer surface operations will finally result in operational benefits for all stakeholders of an airport and will provide important input for an A-SMGCS business case.

EUROCONTROL in co-operation with the European Commission presented results of EMMA and the EUROCONTROL A-SMGCS project to the European Air Navigation Planning Group (EANPG). They presented a formal proposal to update the ICAO A-SMGCS manual [8] and to amend the Regional Supplementary Procedures (SUPPS) (Doc 7030, [7]). These activities are still ongoing.

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Abbreviations

ADS-B	Automatic Dependent Surveillance Broadcast
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service

ANOVA	Analysis of Variance
ANS-CR	Air Navigation Services of the Czech Republic
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASR	Approach Surveillance Radar
ATCO	Air traffic controller
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
AVOL	Aerodrome visibility operational level
BETA	operational Benefit Evaluation by Testing A-SMGCS
CEC	Clearance Executive Controller
CTR	Control Tower Region
CWP	Controller Working Position
DG-TREN	Directorate General Transport and Energy
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EANPG	European Air Navigation Planning Group
EMMA	European airport Movement Management by A-SMGCS
GEC	Ground Executive Controller
GND	Ground
HMI	Human Machine Interface
ILS	Instrumental Landing System
M	Mean
MAEVA	Master ATM European Validation Plan
MLAT	Multilateration
MVP	Machine Vision Processor
NARSIM	NLR ATC Research Simulator
NLR	National Aerospace Laboratory of the Netherlands
ORD	Operational Requirements Document
P	Error probability
RDPS	Radar Data Processing System
RTS	Real Time Simulation
RWY	Runway
SA	Situation Awareness
SASHA	Situation Awareness in the SHAPE project
SDS	Surveillance Data Server
SMR	Surface Movement Radar
SQB	Squitter Beacons
TARMAC	Taxi And Ramp Management And Control
TEC	Tower Executive Controller
TLX	Task Load Index
TPC	Tower Planning Controller
TRD	Technical Requirements Document
TSD	Traffic Situation Display
TWY	Taxiway
V&V	Verification and Validation
VA	VAlidation item number
VE	VErification item number

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Keywords

A-SMGCS, Airport Airside Management, Surface Operations, Operational Trials, Verification, Validation, Human Factors, EMMA, FP6, ATM

Biography

Jörn Jakobi received his diploma in psychology from the University of Göttingen in the year 1999. Since 2000 he is as a human factors expert with DLR institute of flight guidance where he worked in the domain of airport airside traffic management with the focus on A-SMGCS operations and validation. He was coordinating operational trials or performance analyses at diverse European airports in multi-national research projects, like TARMAC or BETA. With the sixth framework 'integrated project' EMMA he was managing the subproject "concept" with 17 European partners from the industry, R&D organisations, airlines and ANSPs and was responsible for all Prague airport related validation activities.

Jürgen Teutsch studied mechanical engineering with a major in aerospace engineering at the Technical University of Aachen (RWTH) and obtained his academic degree with a final examination on GPS-data post-processing carried out at the Faculty of Aerospace Engineering of Delft University of Technology (TUD), the Netherlands, in 1995. After his studies he was involved in a research programme on computer simulation studies of re-entry space-vehicles at TUD. He later worked as a computer consultant for LogicaCMG in Amstelveen, the Netherlands, and as software engineer at the structural dynamics department of EADS Airbus in Hamburg, Germany, before joining the National Aerospace Laboratory of the Netherlands (NLR) in 2000 as manager for ATM simulation projects. Since then he has been involved in several multi-national research initiatives in the area of ATM and airport technologies, among which the most prominent are AFAS, Gate-to-Gate, C-ATM, and EMMA. As validation specialist for the NLR ATC Research Simulator (NARSIM), he has also been involved in the development of the European Operational Concept Validation Methodology (E-OCVM).