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Test Results PRAGUE

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Table of Contents

1 Introduction

The first section of this document contains a description of the project context. The document thereby is positioned within the framework of activities for the 'European Airport Movement Management by A-SMGCS' (EMMA) project [1].

1.1 EMMA Project Background

The 'European Airport Movement Management by A-SMGCS' (EMMA) integrated project is set within the Sixth Framework Program of the European Commission (Directorate General for Energy and Transport) and 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) [4]. 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 fully operational system, the complete proof of benefit of A-SMGCS was missing. Therefore, EMMA is supposed to set the standards for A-SMGCS systems and their operational usage, safety and interoperability while also focussing on the benefit expectation in Europe.

In EMMA an implementation of A-SMGCS Levels I and II will be looked at as an initial step. While the Level I implementation merely seeks to enhance safety and efficiency on the ground by means of additional surveillance services, the Level II implementation already looks at an automated control service which helps controllers to detect potentially dangerous conflicts on runways and restricted areas. In EMMA2 project the focus will be extended to more automated services of A-SMGCS [8]. The new services allow for the sharing of traffic situational awareness among pilots and drivers on the airport and the introduction of an automated routing function. The system will be enhanced with additional functions such as conflict resolution advisories for controllers and the up-link of a validated route planning to pilots and drivers.

1.2 EMMA SP6 Background

Validation in the EMMA framework refers to all activities during the development of A-SMCGS concepts, systems, and procedures aiming at implementing the right concept, procedure, or system. The concept development itself is carried out in EMMA SP1 and thus is not a part of the work in this SP. Developing and implementing the right concepts, procedures and systems (in terms of safety, efficiency, usability etc.) is of utmost importance at a time where advances in ATM are urgently required.

Before successful validation takes place, verification, i.e. testing against system specifications should take place. This Sub-project (SP6) also covers the description of the verification phase. Only if verification results in an A-SMGCS performing at the required level, successful validation of the concept can be started. Therefore, the verification and validation effort (called V&V) also includes the definition of minimum required performance criteria for verification, to allow for successful validation.

In summary (see also Ref. [6]):

Verification is testing against predefined *technical specifications*, technical functional testing ('did we build the system right?').

Validation is testing against *operational requirements* (as defined by stakeholders and written down in the ORD document of EMMA SP1 [10]), man-in-the-loop, ATM procedure testing, case studies ('did we build the right system?').

During the proposal phase of EMMA Phase 1, it was decided to use the 'Master European Validation Plan (MAEVA)' project approach to validation as the basis for EMMA Validation and Verification (V&V). The MAEVA approach is well accepted throughout the European ATM community and has been described in abundant detail in the MAEVA Validation Guideline Handbook, or VGH for short (see Ref. [5]). Nevertheless, several adaptations of MAEVA were proposed in Europe concentrating on the initial approach to validation activities and the related life cycle of the concept or technology to be validated. The "Co-operative Approach to Air Traffic Services" (CAATS) project teams summarised this proposal in their "European Operational Concept Validation Methodology" document, E-OCVM for short (see Ref. [15]), which is European wide accepted now.

EMMA liaised closely with both the MAEVA and the CAATS project teams. The European Commission installed the CAATS project with the objective to co-ordinate safety, Human Factors and validation processes, and methodologies across ATM projects in the Sixth Framework. CAATS identified best practices from these areas and brought the implied knowledge to all projects of the framework. The aim is to provide a co-ordinated approach to bring about the paradigm shift described in the ATM2000+ strategy (Ref. [3]).

1.3 EMMA WP6.3 Context

The work package 6.3 is called "Prague V&V" and includes all test activities linked to simulation and on-site trials related to the Prague controllers and Prague Ruzyne Airport itself. These include:

- Preparation of the Prague V&V infrastructure
- Technical tests (Verification) of A-SMGCS installed in Prague
    - Assess long term surveillance performance data to promote the certification process
    - Assess the alert performance data
- Promote the certification process
- Real Time simulation set-up and integration of the Prague A-SMGCS
    - Controller Training for Prague
    - On-site Benefit Assessment of level I&II use
- Operational Field Trials at Prague airport
    - Controller Training for Prague using the test bed implementation
    - Validate procedures using surveillance information
    - Validate system alert algorithm and procedures

1.4 Scope of the Verification and Validation Exercises

The basic aim of the EMMA Project is the V&V of A-SMGCS Level II functionality as described in the ICAO Manual and further refined in the ORD. EMMA Level II technical and operational functionality is identical to the definition outlined in the official documents of the EUROCONTROL A-SMGCS project. EMMA WP6.3 aims to validate the A-SMGCS Level II concept at Prague-Ruzyně airport.

Four stages of V&V activities have been considered. These are illustrated in the figure below.

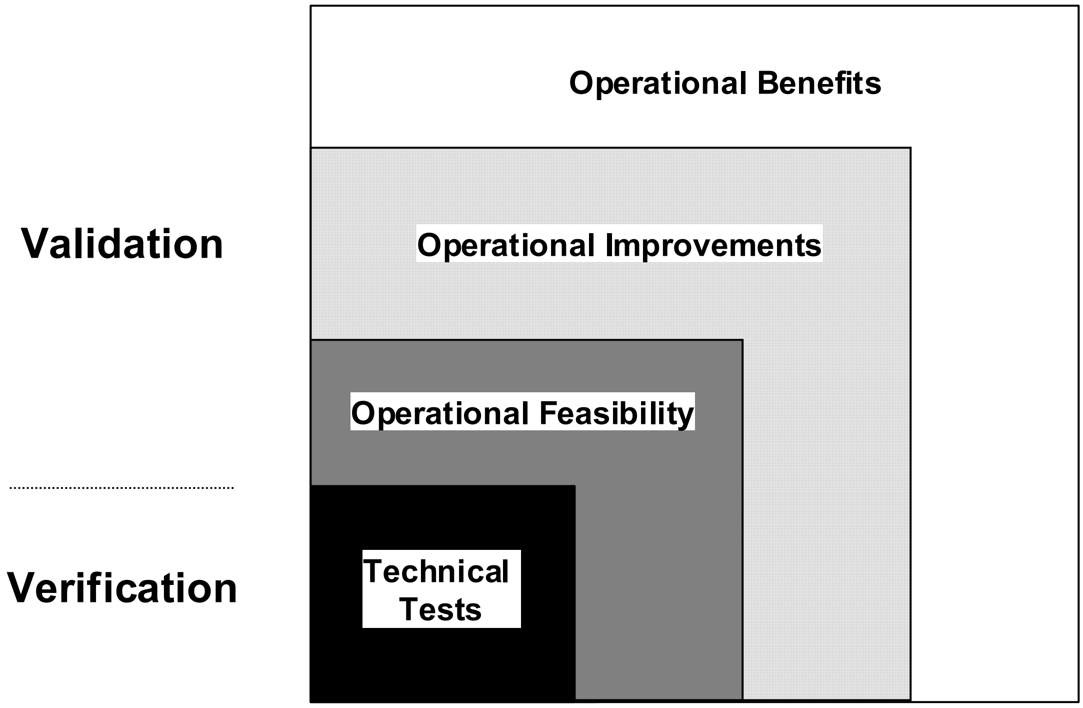


Table 1-1 Stages of V&V Activities

The Technical Tests Stage refers to the tests that should be conducted in order to assess the technical performance of A-SMGCS equipment. It 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 the evaluation 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 improved?"

The Operational Benefits Stage refers to the translation of the operational improvements assessed during the previous stage into terms of economical benefits. It answers the question: "What are the economic benefits for the purchasers and users of A-SMGCS products?"

To summarise, the V&V aims for Prague-Ruzyně airport are as follows:

Verification Aims: To demonstrate that the A-SMGCS (Surveillance and Control functions), provided to the controllers, are implemented in accordance with the technical specifications listed in D3.1.1, Ground System Requirements for Prague-Ruzyně Airport [11] and the D1.4.2a, Technical Requirements Document Part a – Ground [17]. The D142a Technical Requirements have been deduced from the operational requirements listed in D135 ORD [10].

Validation Aims:
The overall aim is to assess the operational feasibility and operational improvements of the Prague-Ruzyně A-SMGCS in achieving its intended operational goals as defined in the D131 OSED document [16] and the D135 ORD document [10].

In general, it can be expected that the validation exercises will demonstrate the Operational Feasibility of the ATM 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, both for airports and for the airborne side, and for different airport operating conditions.

RT-Simulations will focus on the operational feasibility of the monitoring and alert function. The RT-Simulation platform serves as a perfect V&V platform to evoke safety critical events and to tune the system alerts to the needs of the ATCOs. In addition to this main goal operational improvements in terms of safety and efficiency gains shall be proved. Also for this purpose the RTS is a well-suited means.

On-site, V&V activities will concentrate on the measurement of the technical performance and showing the operational feasibility of the whole system. Measuring "operational improvements" in the field are very difficult or even impossible. Frequently, users and the system are not certified for it to be used fully operationally. Furthermore, a valid baseline with ceteris paribus condition compared to the experimental condition (with A-SMGCS) does not exist at all. Weather, traffic mix, traffic amount, runway in use, ATCOs, etc., change frequently and any improvement effects of the A-SMGCS are then overshadowed. However, in the field it has to be shown that the overall system meets the technical performance and operational requirements. When this can be proven, operational improvements, which are measured in the RTS, can be transferred to the real environment.

1.5 Scope of Document

The document is divided into six chapters:

Chapter 1 is this introduction. It describes the background, purpose and scope of the document, the document structure and context, and the methodology used.

Chapter 2 provides the verification results in terms of short and long term **Technical Tests**

Chapter 3 provides all raw data and results of the two **Real Time Simulation** trials

Chapter 4 provides all raw data and results of the **Operational Field Trials**

Chapter 5 provides **conclusions** drawn from the test results

Chapter 6 is an Annex with the flight test scenario description, lists of references, abbreviations, tables and figures.

2 Technical Tests Results

This chapter describes the technical tests performed and the results obtained.

2.1 Introduction

2.1.1 EMMA Test-Bed at Prague Ruzyne Tower

The following figure shows the architecture of the EMMA test-bed system used for the technical tests at Prague.

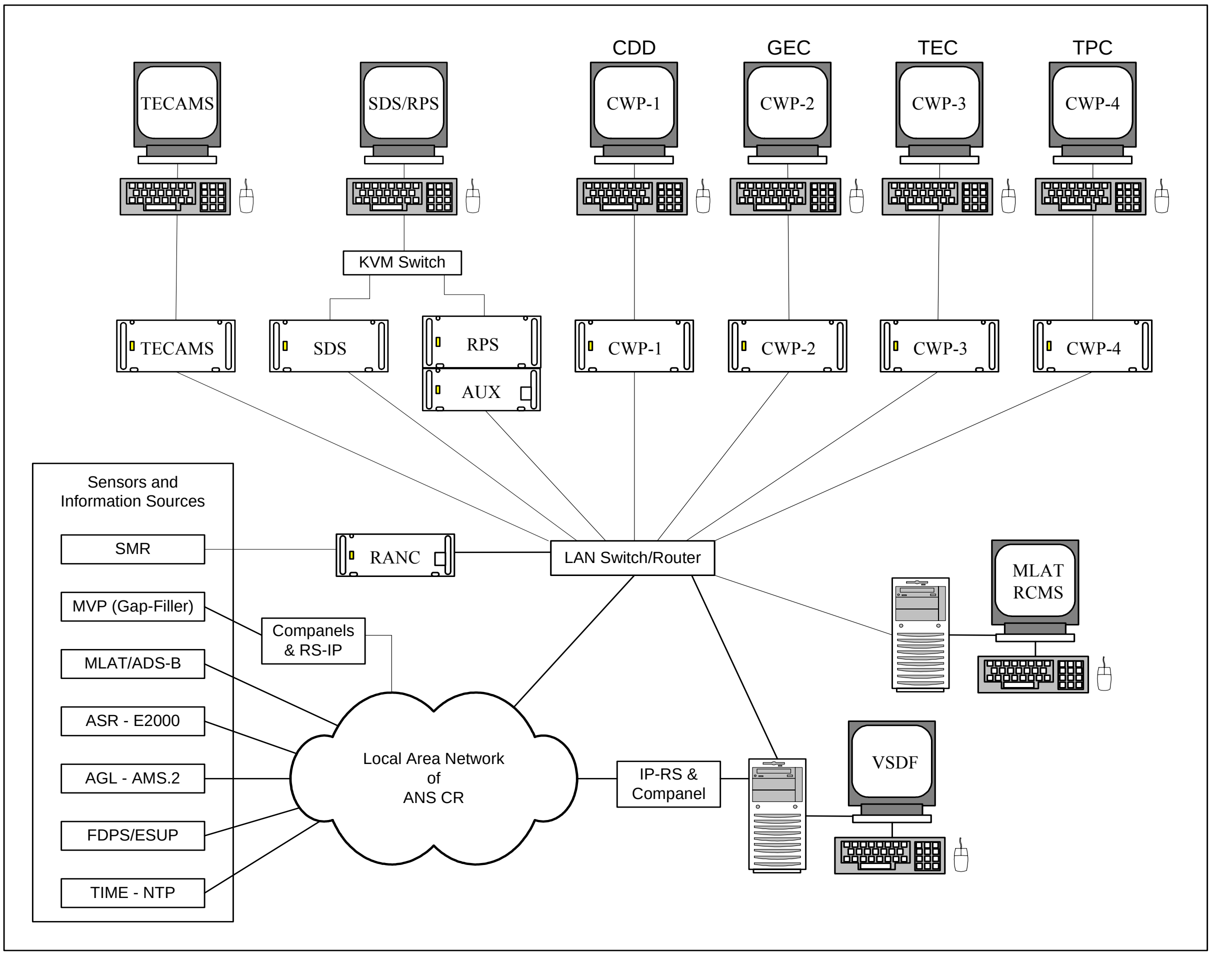


Figure 2-1: EMMA Test-Bed Set-up at Prague

The EMMA test-bed system at Prague-Ruzyně airport consists of a combination of hardware and software components provided specifically for the EMMA project together with the pre-existing infrastructure. This infrastructure includes the surveillance sensors (SMR, MLAT, and ASR-E2000), the Flight Data Processing System (FDPS-ESUP), the Aerodrome Ground Lighting (AGL) system, and the local area network (LAN).

Components provided specifically for the EMMA test-bed comprise the following items:

- Surveillance Data Server (SDS)
- Technical Control and Monitoring System (TECAMS)
- Recording and Playback System (RPS) with Auxiliary Mass Storage Unit (AUX)
- Keyboard/Video/Mouse (KVM) switch

- Controller Working Positions (CWP) denoted CDD, GEC, TEC and TPC
- SMR Extractor (RANC)
- Gap-Filler System, including Machine Vision Processor (MVP) sensors, communication panels (Companels) and RS-485 to Internet converters, and Video Sensor Data Fusion (VSDF)
- MLAT/ADS-B Processing System, including Remote Control and Monitoring System (RCMS)

In addition, forty vehicles belonging to ANS CR and Prague Airport Company were equipped with Mode S squitter beacons (SQB).

Document D3.1.1 Ground System Requirements - Prague [11] describes the EMMA test-bed system and lists the technical requirements.

2.1.2 Indicators and Measurement Instruments

The definition of indicators that were to be measured can be found in the document D6.1.2 Test Plan - Prague [13]. Only the key words and abbreviations are repeated here.

The most important technical performance requirements were to be assessed by 18 verification indicators. Their relation to the TRD, ORD, ICAO, and EUROCAE (MASPS) technical requirements can be seen in the table below.

The verification tests aim primarily at assessing the long-term quality of the surveillance and conflict detection performance. These long-term measurements were to be performed by the recording and analysis tool MOGADOR, which is described in Document D1.1.2 CDG A-SMGCS Data Analysis [14]. Other measurement instruments were Matrices of Detection and Identification, described in the data analysis section below. In addition, short-term tests were to be performed prior to the long-term technical and operational test period in order to assess the readiness of the test-bed system and to verify by visual observation the system's compliance with the technical requirements in D3.1.1 [11].

The following table summarises the indicators and measurement instruments associated with the verification of the technical performance requirements.

ID	Indicator	Acronym	Requirement	Reference	Measurement Instruments
VE-1	Coverage Volume	CV	Approaches Manoeuvring Area Apron taxi lines	TRD: Tech_Surv_01; 02 ORD: Op_Serv-07 ICAO: 4.1.1.4 MASPS: 3.1.3	Recording Observations MOGADOR
VE-2	Probability of Detection	PD	≥ 99.9%	TRD: Tech_Surv_35 ORD: Op_Perf-01 ICAO: 3.4.1.4.a MASPS: 3.2.3	Recording Observations MOGADOR Matrix of Detection
VE-3	Probability of False Detection	PFD	< 10E-3 per Reported Target	TRD: Tech_Surv_36 ORD: Op_Perf-02 ICAO: 3.4.1.4.b MASPS: 3.2.3	Recording Observations MOGADOR Matrix of Detection
VE-4	Reference Point	RP	Not defined	TRD: Tech_Gen_45 ORD: None ICAO: 3.5.7; 4.2.2 MASPS: 3.2.1.2	Recording Observations
VE-5	Reported Position Accuracy	RPA	≤ 7.5 m at a confidence level of 95%	TRD: Tech_Surv_26 ORD: Op_Perf-05; 15 ICAO: 4.2.3 MASPS: 3.2.3	Recording Observations

ID	Indicator	Acronym	Requirement	Reference	Measurement Instruments
VE-6	Reported Position Resolution	RPR	≤ 1 m	TRD: Tech_Surv_27 ORD: Op_Perf-06 ICAO: None MASPS: 3.2.3	Recording Observations
VE-7	Reported Position Discrimination	RPD	Not defined	TRD: None ORD: None ICAO: None MASPS: None	Recording Observations
VE-8	Reported Velocity Accuracy	RVA	Speed: ≤ 5 m/s Direction: ≤ 10° at a confidence level of 95%	TRD: Tech_Surv_28; 29 ORD: Op_Perf-16 ICAO: 4.1.1.8, 4.1.1.10 MASPS: 3.2.3	Recording Observations
VE-9	Probability of Identification	PID	≥ 99.9% for identifiable Targets	TRD: Tech_Surv_37 ORD: Op_Perf-03 ICAO: 3.4.1.4.c MASPS: 3.2.3	Recording Observations MOGADOR
VE-10	Probability of False Identification	PFID	< 10E-3 per Reported Target	TRD: Tech_Surv_38 ORD: Op_Perf-04 ICAO: 3.4.1.4.d MASPS: 3.2.3	Recording Observations MOGADOR
VE-11	Target Report Update Rate	TRUR	≤ 1 s	TRD: Tech_Surv_34 ORD: Op_Perf-08 ICAO: 4.2.4 MASPS: 3.2.3	Recording Observations
VE-12	Probability of Detection of an Alert Situation	PDAS	≥ 99.9%	TRD: Tech_Cont_11 ORD: None ICAO: 4.5.1 MASPS: 3.3.3	Recording Observations
VE-13	Probability of False Alert	PFA	< 10E-3 per Alert	TRD: Tech_ Cont_12 ORD: Op_Perf-20 ICAO: 4.5.1 MASPS: 3.3.3	Recording Observations
VE-14	Alert Response Time	ART	≤ 0.5 s	TRD: Tech_ Cont_13 ORD: None ICAO: 4.5.2 MASPS: 3.3.3	Observations
VE-15	Routing Process Time	RPT	≤ 10 s	TRD: None ORD: None ICAO: 4.3.2	Not applicable for Prague
VE-16	Probability of Continuous Track	PCT	Not specified	TRD: None ORD: None ICAO: None MASPS: None	Recording MOGADOR
VE-17	Matrix of Detection	MOD	Not specified	TRD: None ORD: None ICAO: None MASPS: None	Recording MOGADOR

ID	Indicator	Acronym	Requirement	Reference	Measurement Instruments
VE-18	Matrix of Identification	MOI	Not specified	TRD: None ORD: None ICAO: None MASPS: None	Recording MOGADOR

Table 2-1: Technical Verification Indicators

2.2 Raw Data

Raw data was gathered during Site Acceptance Testing (SAT) of the EMMA test-bed system carried out at Prague Ruzyně airport in the period 14-18 March 2005.

Site acceptance testing concentrated mainly on the specific items provided for the EMMA Test-Bed. However, to prepare the way for the operational verification and validation exercises in SP6, the SAT also included basic technical performance verification tests of the overall A-SMGCS including the existing surveillance sensors. These technical verification tests and the results obtained are described in this section.

The objectives of the SAT were to verify the correct function of the EMMA test-bed system and to demonstrate that the technical requirements defined in deliverable document D3.1.1 Ground System Requirements - Prague [11] had been fulfilled.

The SAT was performed by Park Air Systems personnel with the assistance of ANS CR and witnessed by ANS CR.

Supplementary tests were performed in the period 8-11 November 2005.

Testing consisted mainly of visual observation of the traffic situation displays at the controller working positions in the EMMA test room (old TWR) while observing the live traffic through the window. In addition, a follow-me vehicle equipped with a 1090ES squitter beacon (SQB) was directed to perform various manoeuvres in order to gather data for the measurement of specific verification indicators.

All relevant data was continuously recorded throughout the trial period for later analysis.

The data collected consisted of recordings in Park Air proprietary format and included:

- Target reports from all surveillance sensor systems
- Flight plan data
- Target reports from the surveillance data fusion process of the SDS
- Operator actions at the CWPs
- Alerts
- Airport context data

During a replay session, this recorded information is sufficient to permit the full reconstruction of all information displayed at any CWP.

The archive media is Advanced Intelligent Tape ™ (™ Sony AIT).

2.3 Results

Except for the performance indicator results derived in this section, the full list of technical requirements for the Prague test-bed, with the related acceptance tests and the results obtained, is given in document D3.6.1 Site Acceptance Test Report - Prague [12]. The main objective of the site acceptance tests was to ensure that the performance of the EMMA test-bed system was adequate to permit the system to be used for operational tests.

Some requirements were verified by visual observation, others by analysing recorded data to obtain quantitative results. These tests and the results obtained are described below.

The MOGADOR tool was used to perform automatic long-term observations of the system surveillance performance. Data were compiled and analysed over a period of 4 weeks. The tool can locate blind spots and output maps with blind spots for the different conditions.

The data are analysed by taking into account different independent variables:

- Different traffic objects that operate on the airport (aircraft, vehicles, unknown)
- Different weather conditions (no snow and precipitation vs. snow or and precipitation)
- Different zones of the aerodrome (Runway, Obstacles Free Zone [OFZ], Taxiways)

In the test descriptions that follow, each indicator is presented under a separate heading in the following format:

- Indicator ID - a unique, unambiguous identifier for each indicator.
- Hypothesis - the specification of the requirement or definition of the indicator to be tested
- Test Procedure - the description of the test method, or a statement of how the requirement has been fulfilled without the need for a specific test. In some cases, the test procedure is split into short-term and long-term tests.
- Result - the result of the test, including analysis of the test data where applicable

2.3.1 Coverage Volume (VE-1)

Hypothesis VE-1	The A-SMGCS equipment should provide surveillance coverage throughout the Movement Area up to a height of at least 200 feet above the Aerodrome surface, and on the approaches to each runway out to a distance of 10 NM.

Test Procedure

a) Short-Term Test (performed at SAT)

The Coverage Volume (CV) was tested by visual observation transiting the Movement Area of interest with a test vehicle and recording the target report position and identification data. Coverage was also confirmed by observing the HMI.

All aircraft and vehicle movements, non-cooperative as well as cooperative, were recorded over a period of one hour with heavy traffic. The recordings included airborne aircraft on the approaches to the airport.

Weather conditions at the time of the test were noted.

Result

a) Short-Term Test

The following figure shows the Prague Ruzyně airport layout at the date of the test.

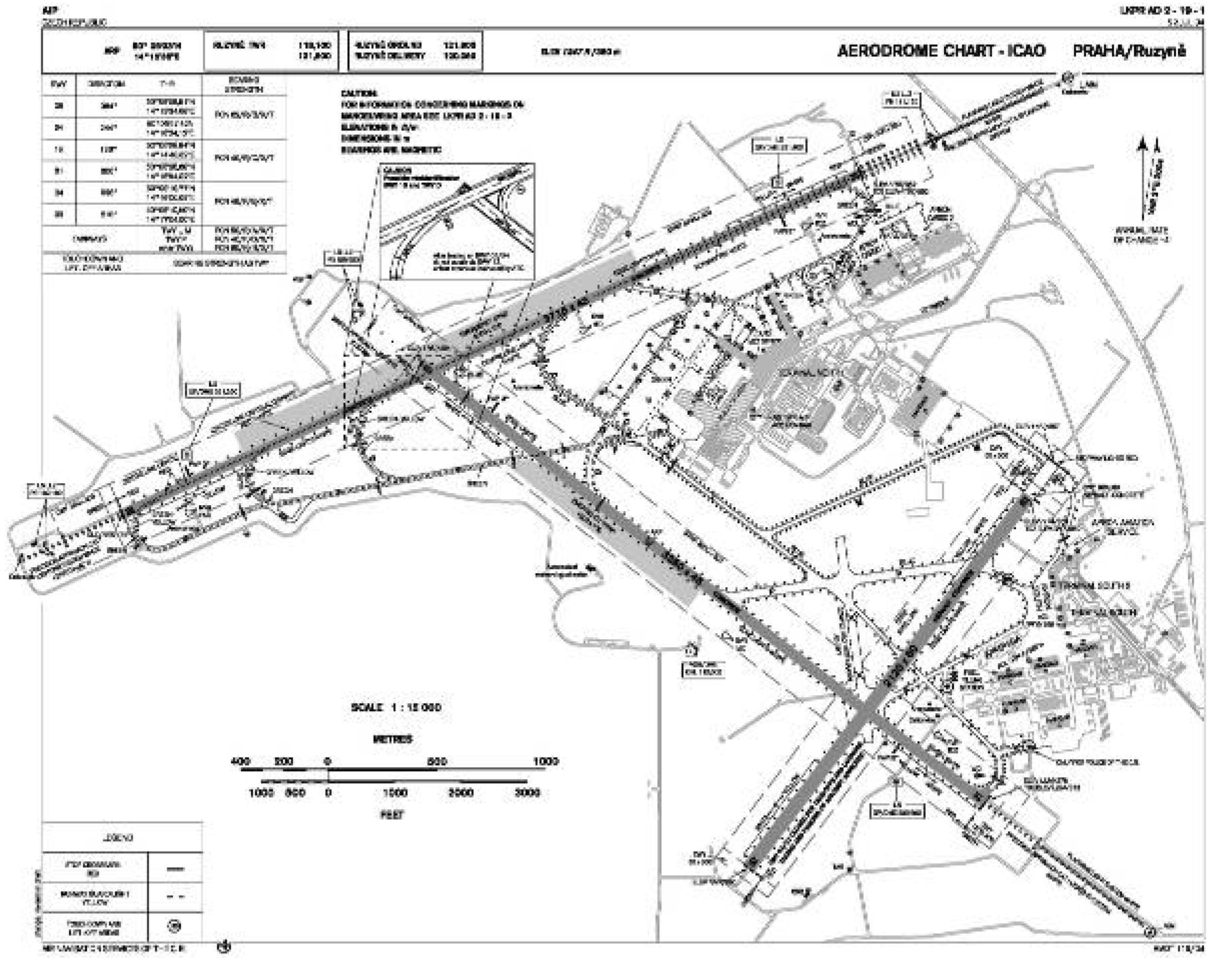


Figure 2-2: Prague Ruzyně Airport Layout

Aerodrome Status: Taxiways C and D and northern end of RWY 31 were closed throughout the test period due to construction of new rapid exits. Pier C was under construction.

The following figure shows the trajectories of all traffic within 10NM of the airport during the hour of recording. The trajectories are the position reports recorded at the output of the surveillance data server (SDS).

Weather condition: Fine and clear, no precipitation.

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

During the period of the recording, runways 06 and 31 were in use, both in mixed mode.

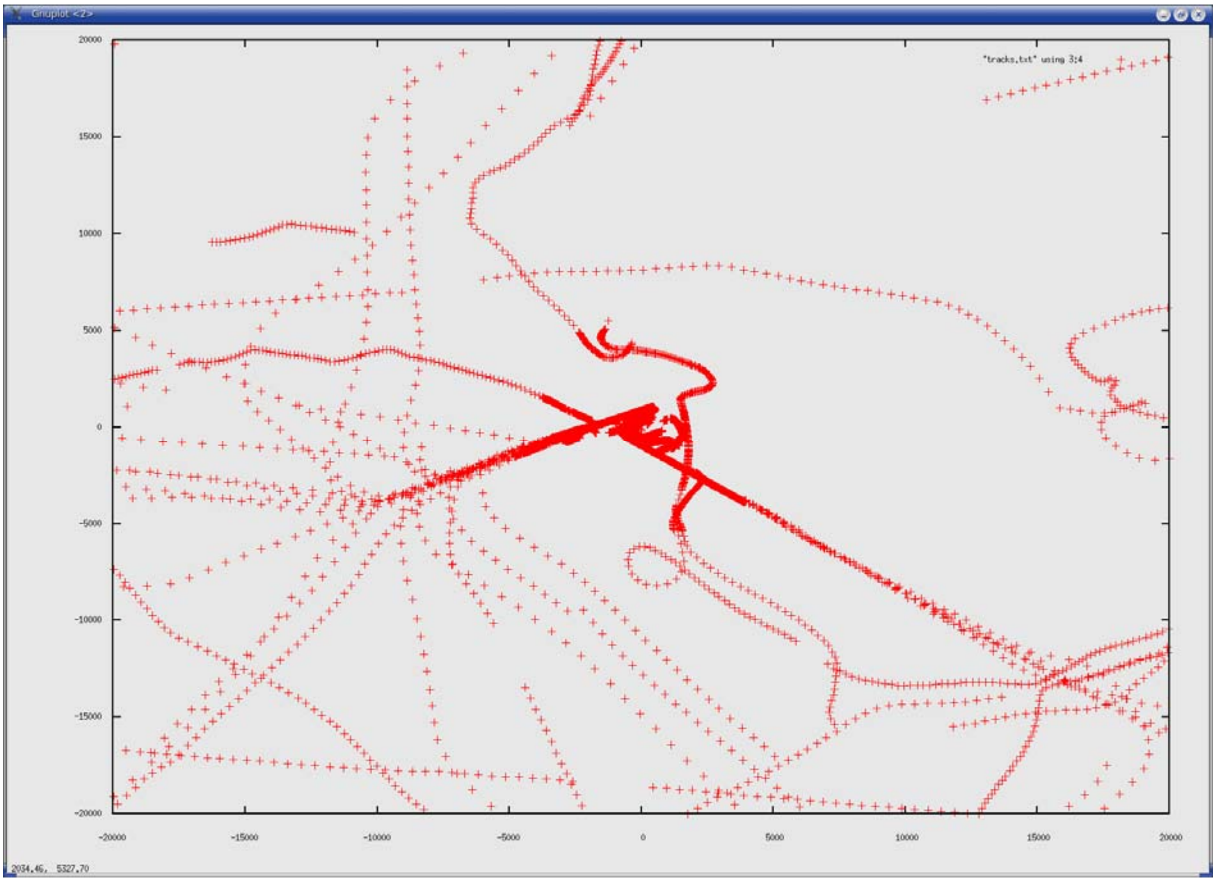


Figure 2-3: Plot Showing Coverage out to 10NM during CV Test

Note that the target report update rate for airborne traffic is higher close to the airport where the traffic is within range of the MLAT system. Farther out, the only sensor contributing to the track is the approach radar (with a 6 second update rate).

The following figure shows the trajectories of all ground traffic on the movement area of the airport during the hour of recording. The trajectories are the position reports recorded at the output of the surveillance data server (SDS).

Sensors contributing are MLAT, SMR, and GFS.

Weather condition: Fine and clear, no precipitation.

File: "alltracks.txt" recorded 16 March 2005, 10:40 to 11:40 UTC.

During the period of the recording, runways 06 and 31 were in use, both in mixed mode.

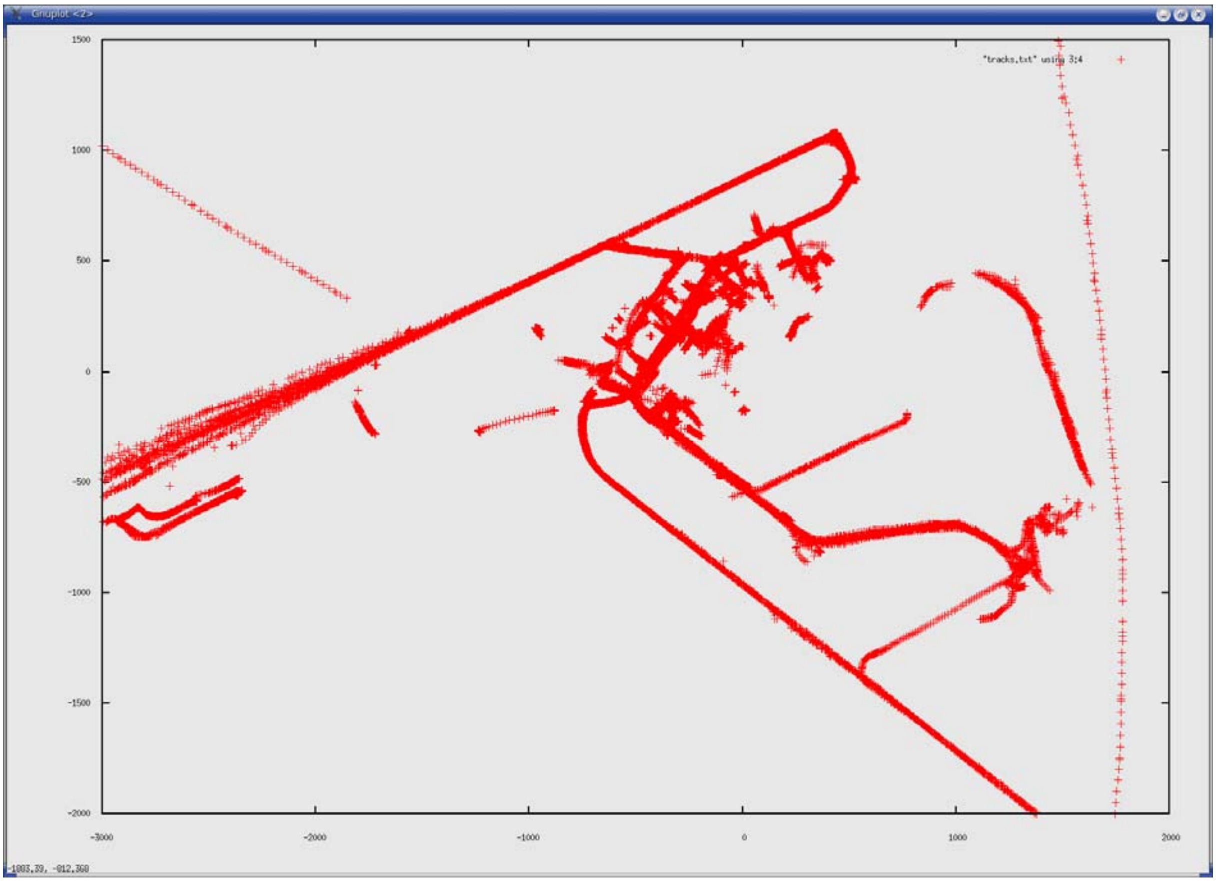


Figure 2-4: Plot Showing Ground Traffic Trajectories during CV Test

The following figure shows the single trajectory of the test vehicle "FOLLOW 3" that was used to check the coverage.

The trajectory is generated using the trajectory function on the RPS Playback.

Sensors contributing are MLAT, SMR, and GFS.

Weather condition: Fine and clear, no precipitation.

File: "Follow3.txt" recorded 15 March 2005, starting at 13:30 UTC.

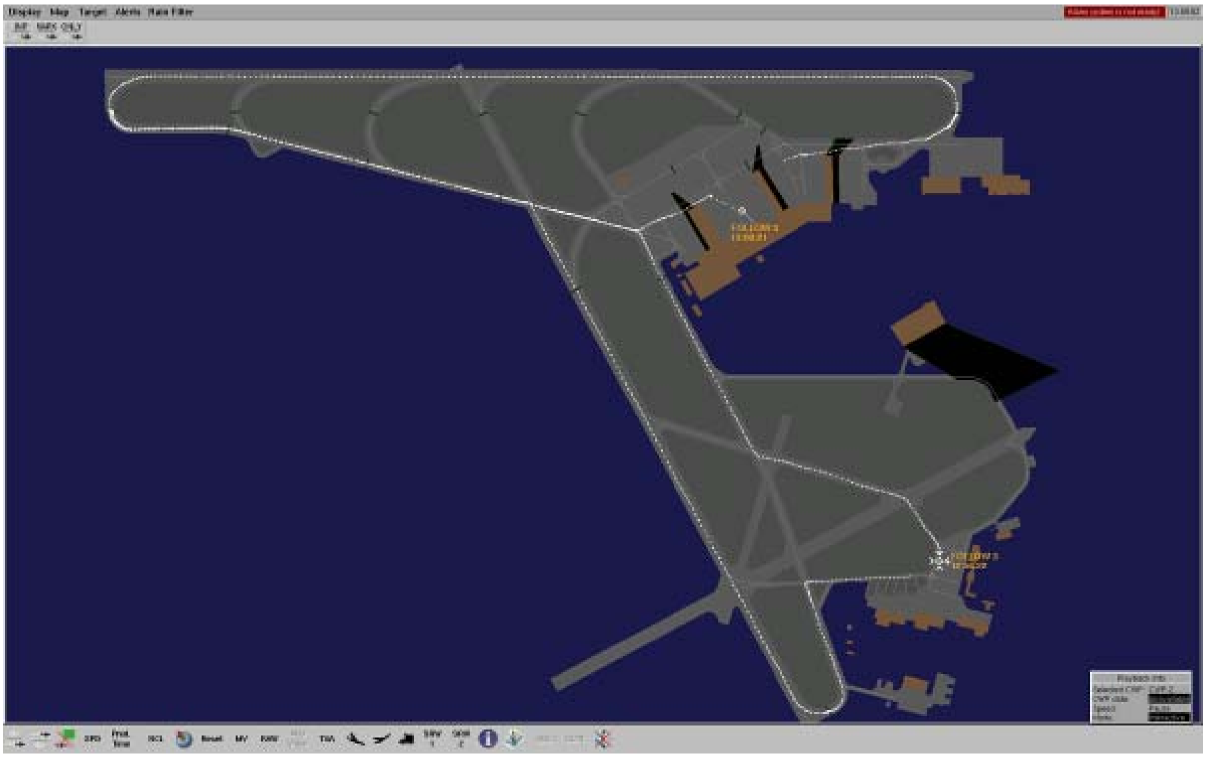


Figure 2-5: Playback Image Showing Trajectory of Test Vehicle during CV Test

The test vehicle started from Pier B, proceeded via TWY A to Hold at stop bar for RWY 24; Drove the whole length of RWY 24, exited on TWY F and proceeded along F to L crossing RWY 1331; Drove South on L, then via P to South Apron. After stop on apron, the vehicle proceeded via R and L to hold at stop bar for RWY 31. Drove RWY 31 as far as TWY F; proceeded along F to hold at stop bar for RWY 06. Returned via F to North Apron.

b) Long-Term Test (MOGADOR)

No long-term analysis of CV was performed for VE-01. As coverage volume the whole Movement Area is taken into consideration.

2.3.2 Probability of Detection (VE-2)

Hypothesis VE-2	The probability that an actual aircraft, vehicle, or object is detected and reported at the output of the SDS should be 99.9% at minimum.

<u>Test Procedure</u>

a) Short-Term Test (performed at SAT)

The test scenario was the same as the CV test (see VE-1 above).

The recorded data for the test vehicle and for a selection of identified aircraft was used to calculate the Probability of Detection (PD) as follows:

> Reports that were found to be inaccurate (> 20m from expected position for ground, > 200m for airborne) or not timely (> 1.5 seconds old) were discarded. The remaining reports were considered as correct reports.

The expected number of reports is: $\frac{\textit{Time of the last report - Time of the first report}}{TRUR} + 1$

Then, $PD = \frac{Number\ of\ correct\ reports}{Expected\ number\ of\ reports}.100\%$

b) Long-Term Test (MOGADOR)

The test scenario was the same as for the CV test (see VE-1 above).

First, the MOGADOR tool was used to calculate the PD for the same data as for the short-term tests. This MOGADOR result was compared with the calculated value to confirm that the MOGADOR was correctly calibrated.

MOGADOR was then used to assess the PD for the longer period (4 weeks).

Results

a) Short-Term Test

Weather condition: Fine and clear, no precipitation.

File: “Follow3.txt” recorded 15 March 2005, starting at 13:30 UTC.

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

Area	Mobile Type	Expected No. of Reports	No. of Correct Reports	PD
RWY	Aircraft	1472	1471	99.93%
	Test vehicle	251	251	100%
TWY	Aircraft	2830	2820	99.65%
	Test vehicle	1730	1730	100%
Approach	Aircraft	1167	1165	99.83%

Table 2-2: Results of Probability of Detection Test

b) Long-Term Test (MOGADOR)

For the evaluation three days with good weather-conditions (no snow, no precipitation) and seven days with non-optimal conditions (snow, sunshine, and precipitation) are taken into consideration. The following figures show the results for the PD for the different types of mobiles (All, Aircraft, Vehicle, and Unknown) and the three locations Runways, Obstacle Free Zone (OFZ) and Taxiways. The results are grouped by the named weather conditions.

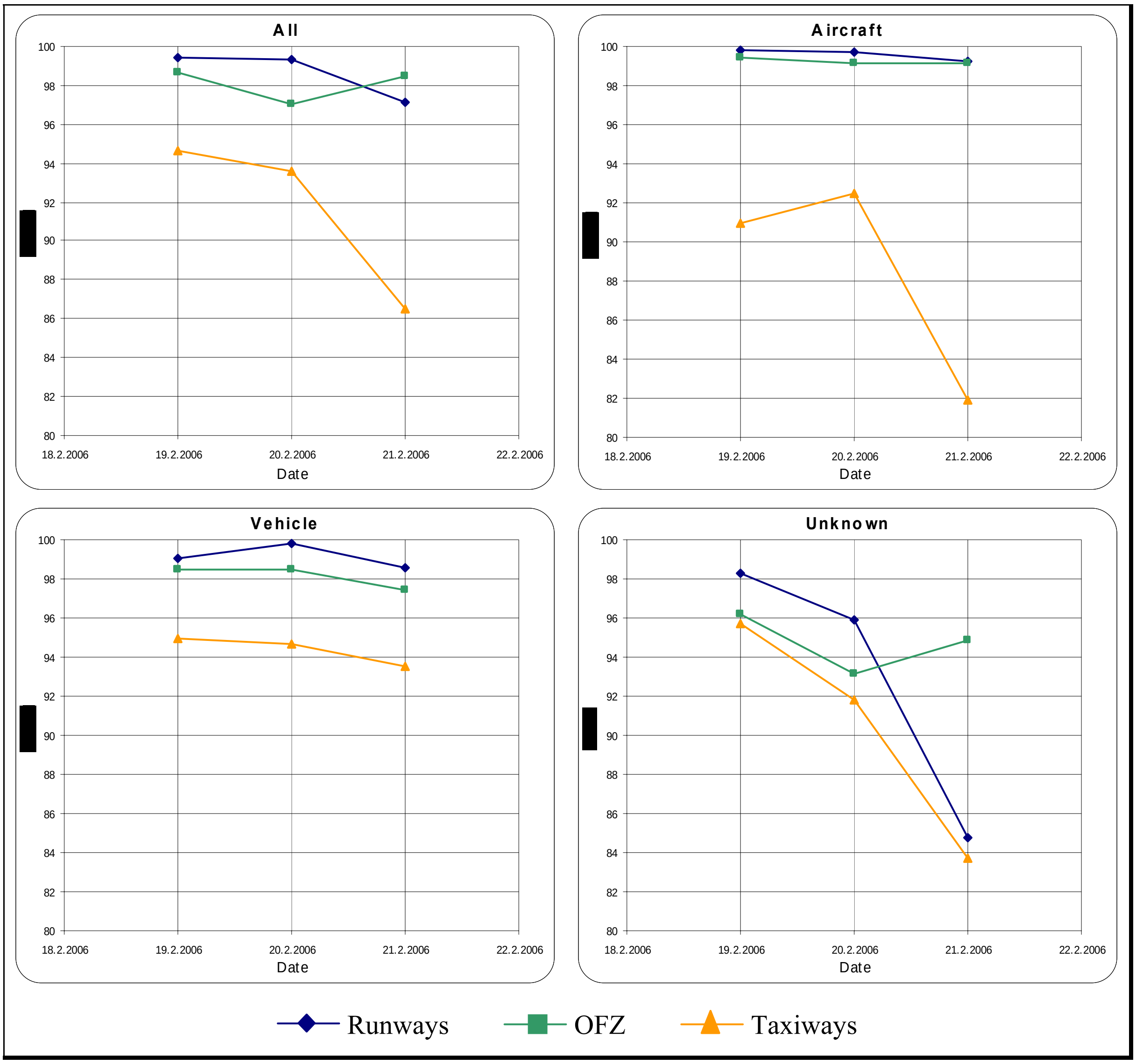


Figure 2-6: PD Long Term Observation (excellent weather conditions (no snow, no precipitation))

While the PD for Aircraft and Vehicle on Runways and Taxiways in good weather stays on a high level (AC 99.2-99.8%, Vehicle 97.5-99.7%), the PD for Unknown mobiles varies from 83.7-98.3%. The values for the Taxiways are significantly lower.

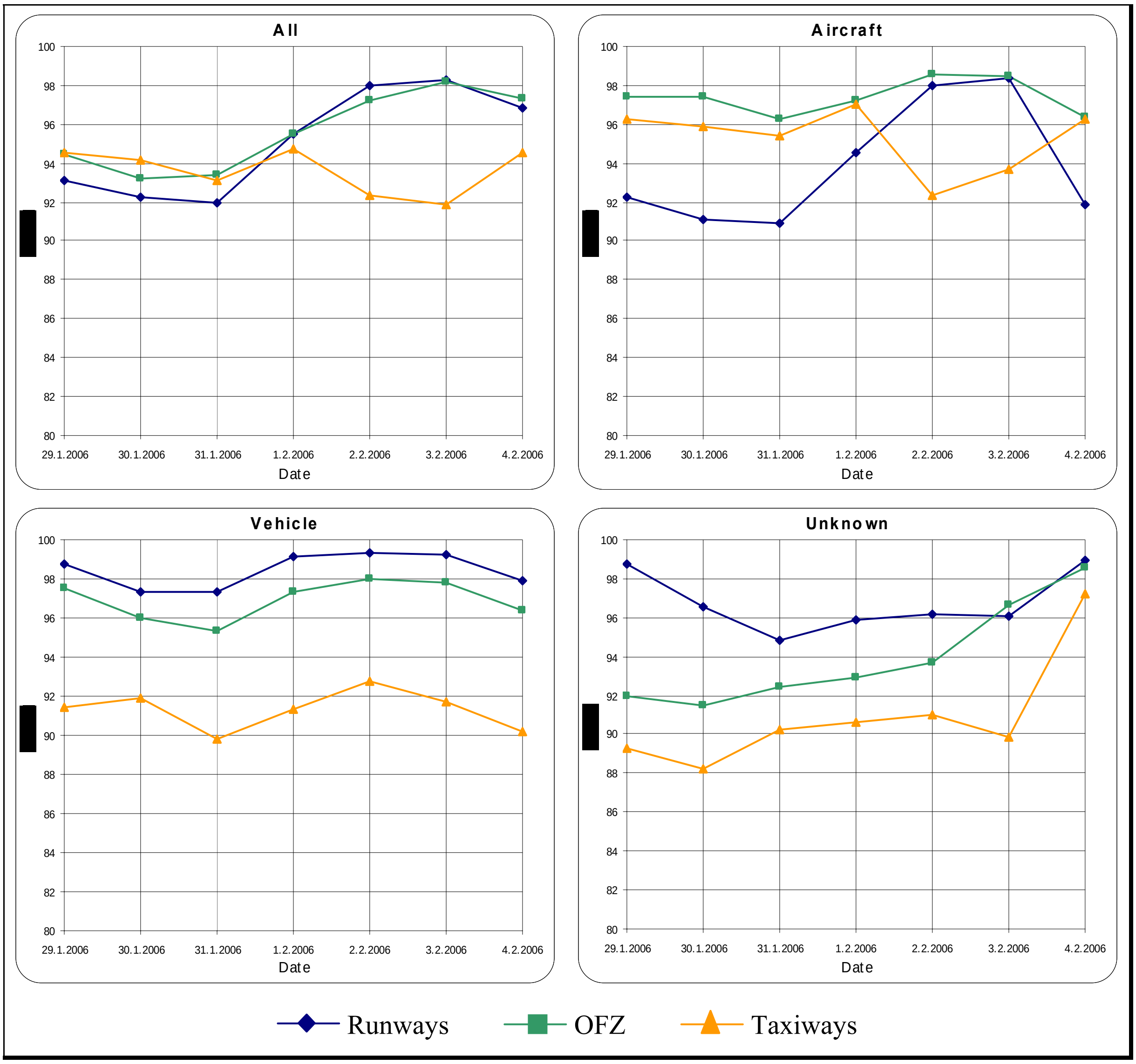


Figure 2-7: PD Long Term Observation (no optimal weather conditions (snow)

In non-optimal weather conditions, a reduction of the PD can be seen. For “All” the PD has a minimum of 92% (Runway and Taxiways) and a maximum of 98% (Runways and OFZ).

During the analysis with MOGADOR, it has been discovered that reports of tracks are rejected by the tool. This happens if tracks are crossing the apron area (which has been masked out by MOGADOR) or running besides the RWY after take-off. The path reconstruction function is used to combine isolated reports and track-parts with other tracks. For Prague airport, reports have been added to tracks which do not belong to them. It has been identified that the tuning of the parameters of MOGADOR has a big influence on the results. It needs a lot of time to get this function working properly. Furthermore, a correct, highly accurate, and a current topology for the airport is necessary. All the mentioned facts lead to the result, that the PD is very different from day to day.

2.3.3 Probability of False Detection (VE-3)

Hypothesis VE-3	The probability that anything other than an actual aircraft, vehicle, or object is detected and reported at the output of the SDS should not exceed 10E-3 per reported target.

Test Procedure

a) Short-Term Test (performed at SAT)

The test scenario was the same as for the CV test (see VE-1 above).

The recorded data was used to calculate the Probability of False Detection (PFD) as follows:

The number of erroneous reports was found by summing reports not corresponding to known obstacles (considering the required accuracy) with the discarded reports from known mobiles that do not meet accuracy and timeliness requirements (see PD test for values).

Then, $PFD = \frac{Number\ of\ erroneous\ reports}{Total\ number\ of\ reports} \cdot 100\%$

b) Long-Term Test (MOGADOR)

First, the MOGADOR tool was used to calculate the PFD for the same data as for the short-term tests. This MOGADOR result was compared with the calculated value to confirm that the MOGADOR was correctly calibrated. MOGADOR was then used to assess the PFD for the longer period (4 weeks).

Result

a) Short-Term Test

Weather condition: Fine and clear, no precipitation.

File: “Follow3.txt” recorded 15 March 2005, starting at 13:30 UTC.

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

Area	Mobile Type	Expected No. of Reports	No. of Erroneous Reports	PFD
RWY	Aircraft	1472	1	0.07%
	Test vehicle	251	0	0.00%
TWY	Aircraft	2830	2	0.07%
	Test vehicle	1730	0	0.00%
Approach	Aircraft	1167	2	0.17%

Table 2-3: Results of Probability of False Detection Test

b) Long-Term Test (MOGADOR)

For the evaluation, three days with good weather-conditions (no snow, no precipitation) and seven days with non-optimal conditions (snow, precipitation) are taken into consideration. The following figures show the results for the PFD for the different types of mobiles (All, Aircraft, Vehicle, and Unknown) and the three locations Runways, Obstacle Free Zone (OFZ), and Taxiways. The results are grouped by the named weather conditions.

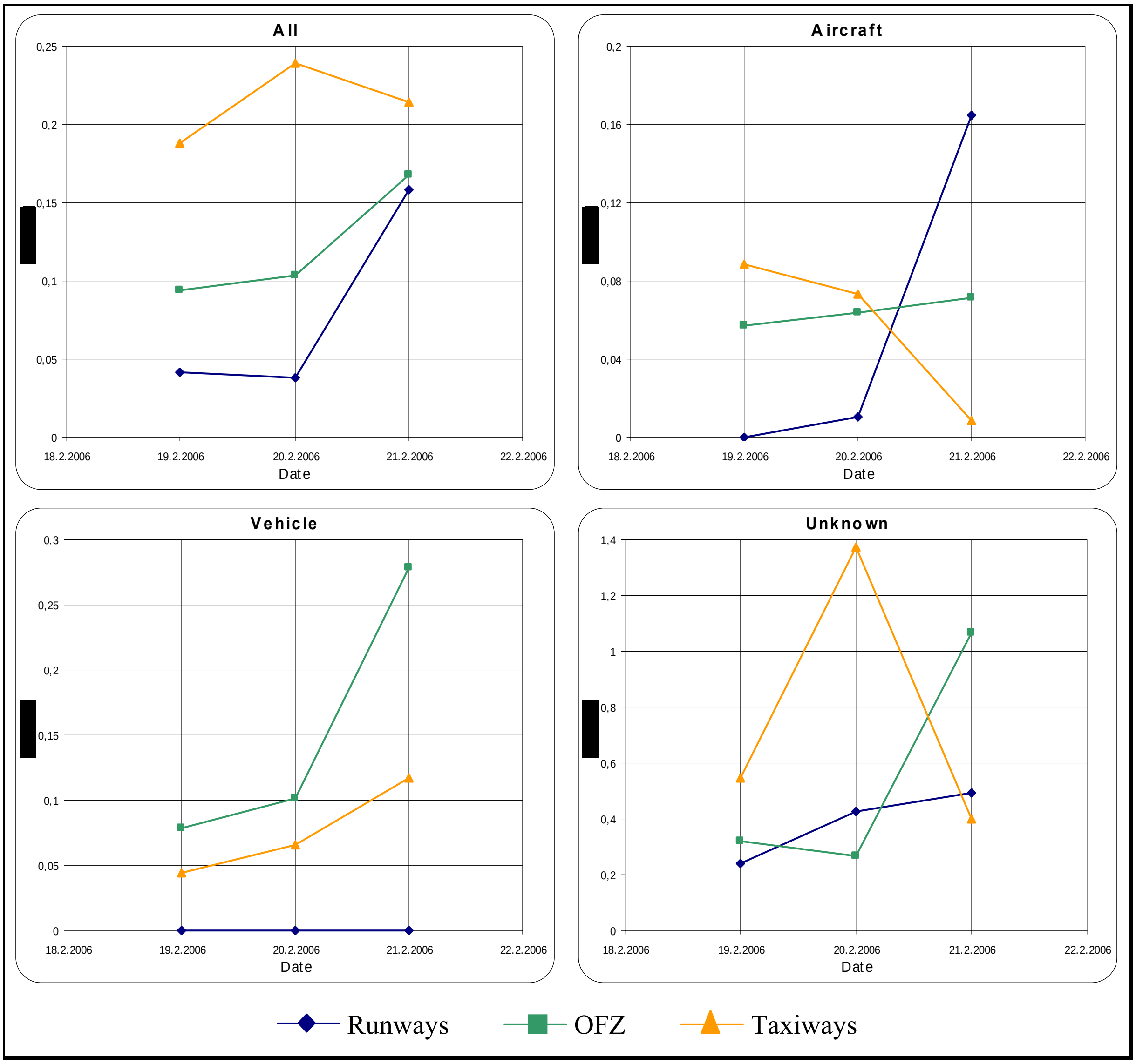


Figure 2-8: PFD Long Term Observation (excellent weather conditions (no snow, no precipitation))

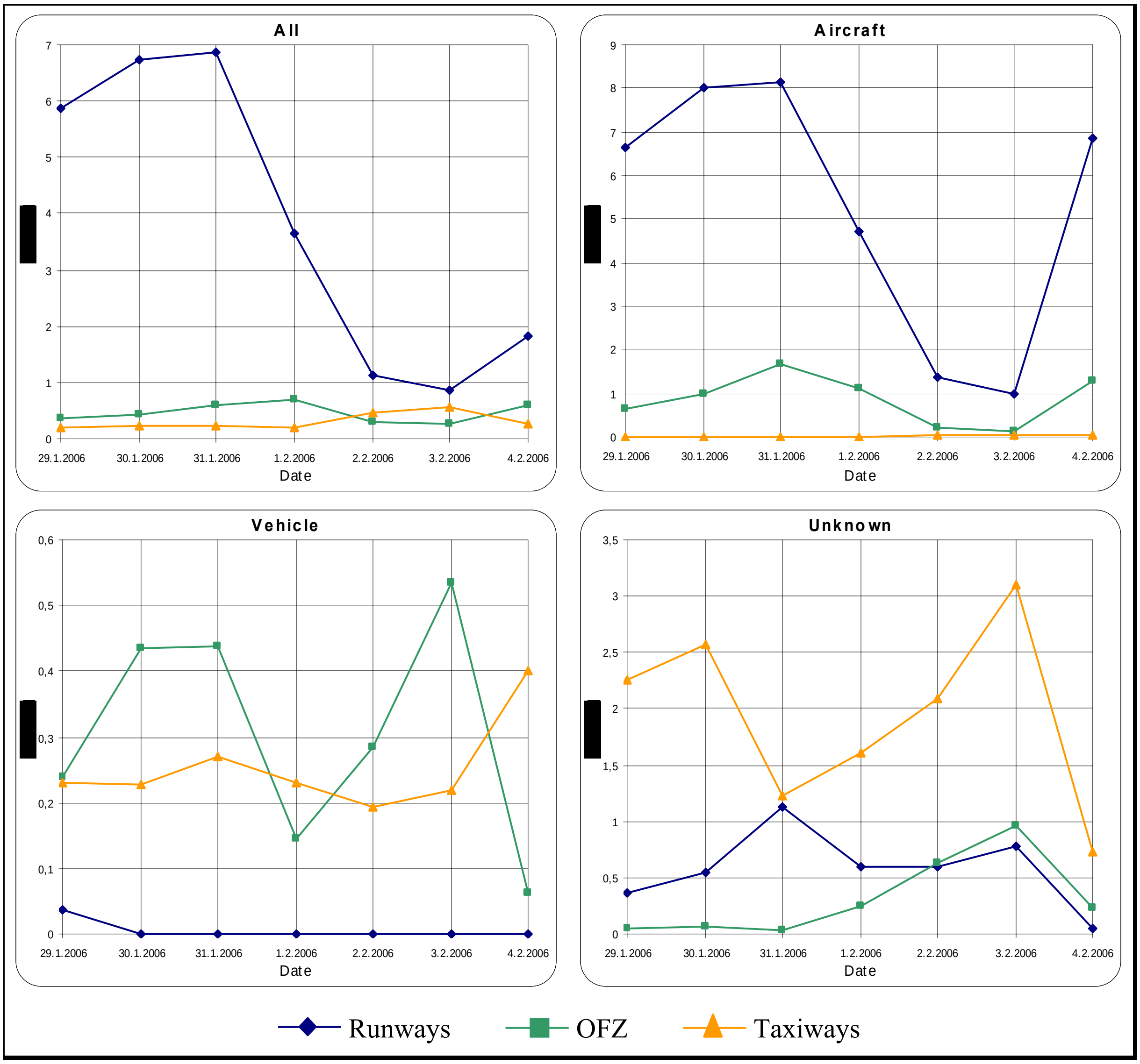


Figure 2-9: PFD Long Term Observation (no optimal weather conditions (snow))

The analysis of the PFD with MOGADOR has shown that the differences of the PFD-value are big during bad weather. This also indicates that the result do not depend only on the weather, but are probably caused by inadequate tuning of the MOGADOR tool to the Prague airport conditions.

2.3.4 Reference Point (VE-4)

Hypothesis VE-4	A reference point on aircraft and vehicles is required to enable the A-SMGCS to determine their positions.

Test Procedure

The recommended common reference point is the geometric centre of the aircraft or vehicle. The aim of this test was to measure the bias between the reported position of the target and the target reference point, especially for medium and large aircraft.

The test scenario was the same as for CV (see VE-1 above).

The recorded data was played back and used to observe stationary aircraft on the Controller HMI and to estimate the reported position compared with the actual position of the centre of the aircraft as shown by the SMR video image. Measurements were made for aircraft on different parts of the airport, with different headings with respect to the SMR,

Result

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

Mobile Type	RP (m)
Small Vehicle	< 2 m
Small Aircraft (Cessna)	< 3 m
Medium Aircraft (ATR)	< 7 m
Large Aircraft (B737)	< 12 m
Very Large Aircraft (B747)	< 20 m

Table 2-4: Results of RP Test

In all cases, the value of RP represents the displacement of the position symbol of the mobile on the CWP traffic situation display with respect to the centre of its SMR image. The position symbol is displaced because the data fusion gives most weight to the MLAT position reports, locate the position of the aircraft’s Mode S transmitting antenna. In the case of an aircraft, the direction of the displacement is always towards the nose; for a vehicle, it may be in any direction, depending on where the antenna has been mounted.

In the longer term, the data fusion algorithm could be improved to take account of this displacement if the system knows the aircraft type and the direction in which the aircraft is heading.

The following picture shows a queue of medium and large aircraft holding at a runway entry point.
The displacement of the target position symbol towards the front of the aircraft can be clearly seen.

Figure 2-10: Row of Holding Aircraft showing Location of Position Symbol relative to SMR Image

2.3.5 Reported Position Accuracy (VE-5)

Hypothesis VE-5	The reported position accuracy of the surveillance data transmitted from the SDS to clients should be 7.5m or better at a confidence level of 95%.

Test Procedure

a) Static

The test vehicle FOLLOW3 was driven to stop bar positions in six different areas of the airport. At each stop bar, the vehicle was positioned with its centre at the junction of the taxiway centreline and the stop bar line, where it remained stationary for at least 30 seconds. Target report data was recorded for later analysis.

Weather conditions at the time of the test were noted.

From the recorded data, the 95% Reported Position Accuracy (RPA) was calculated according to EUROCAE guidelines as follows:

For each position report the errors in the X position, Δx, and in the Y position, Δy, were calculated:

Δx = (Known X position - Reported X position) in metres

Δy = (Known Y position - Reported Y position) in metres

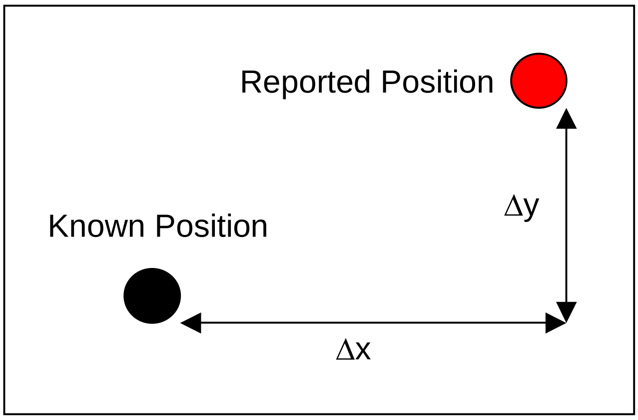


Figure 2-11: X and Y Components of Position Error

The resulting data was used to calculate the mean X and Y errors according to the following formulae, where i = 1,2,3,…n and n is the number of reports:

Mean deviation in X, $m_x = \sum \Delta x_i/n$

Mean deviation in Y, $m_y = \sum \Delta y_i/n$

Then, the RPA was calculated using the following formulae:

$R_x = C*\sqrt{(\sum (\Delta x_i - m_x)^2/n)} + m_x$

$R_y = C*\sqrt{(\sum (\Delta y_i - m_y)^2/n)} + m_y$

$RPA = \sqrt{(R_x^2 + R_y^2)}$

Where the coefficient C is set to 1.960 for the required 95% confidence level.

b) Dynamic

The test vehicle made a series of manoeuvres as it drove around the Movement Area. These are the following manoeuvres:

- Straight-line acceleration and deceleration on the runway
- Driving at constant speeds along a runway and straight stretches of taxiway
- Turning corners
- Deceleration from high speed to stop at a stopbar

Observation of the target reports on the Controller HMI when compared with the actual position of the vehicle was used to estimate the deviation.

Result

a) Static

Weather condition: Fine and clear, no precipitation.

Location	Coordinates	n	m_x	Rx	m_y	Ry	RPA
Stopbar A	497.2, 865.4	83	-0.67	1.99	-1.43	1.12	2.29
Stopbar F	-2823.2, -615.5	52	-2.77	-1.60	0.70	2.73	3.16
Stopbar L	1101.7, -1658.4	395	-0.42	0.35	-1.01	-0.30	0.46

Table 2-5: Static RPA Test Results

Worst-case static RPA: 3.16 m

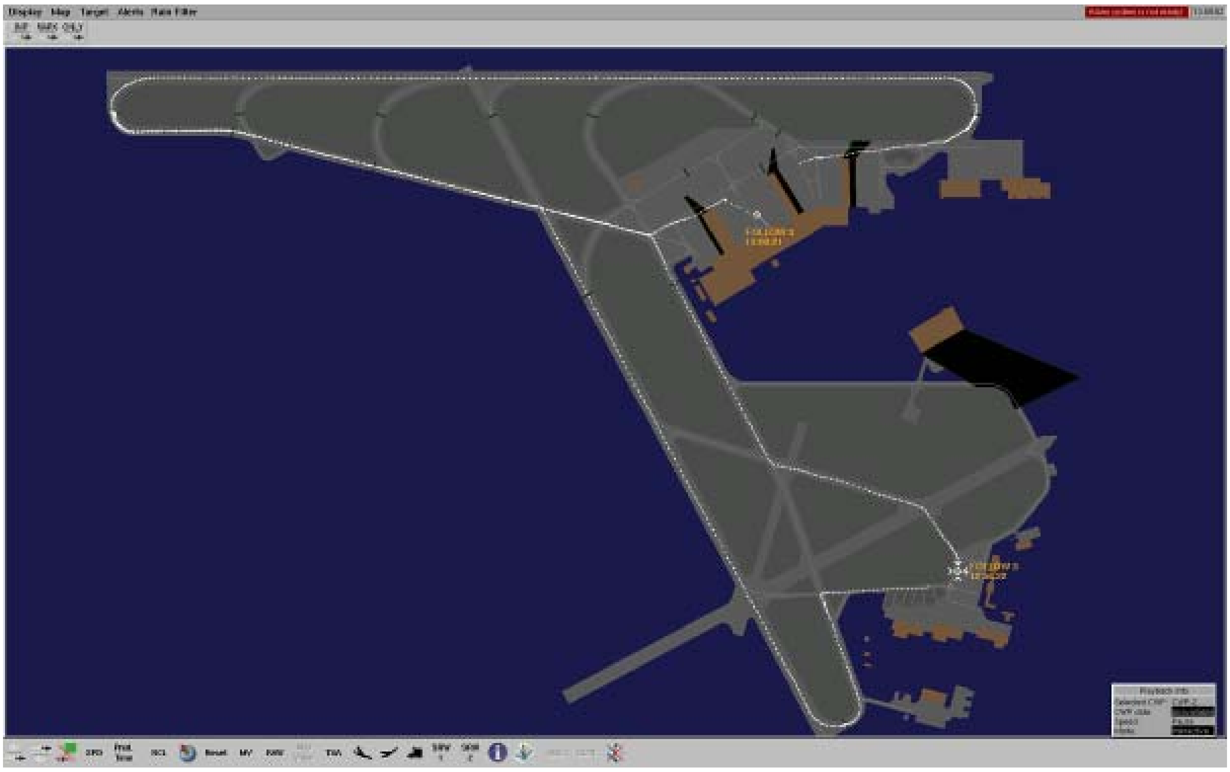


Figure 2-12: Replay Showing part of Test Vehicle Trajectory during Test

The picture shows the trajectory of the test vehicle during part of the test.

The test vehicle started from Pier B, proceeded via TWY A to Hold at stop bar for RWY 24; Drove the whole length of RWY 24, exited on TWY F and proceeded along F to L crossing RWY 1331; Drove South on L, then via P to South Apron. After stop on apron, the vehicle proceeded via R and L to hold at stop bar for RWY 31. Drove RWY 31 as far as TWY F; proceeded along F to hold at stop bar for RWY 06. Returned via F to North Apron.

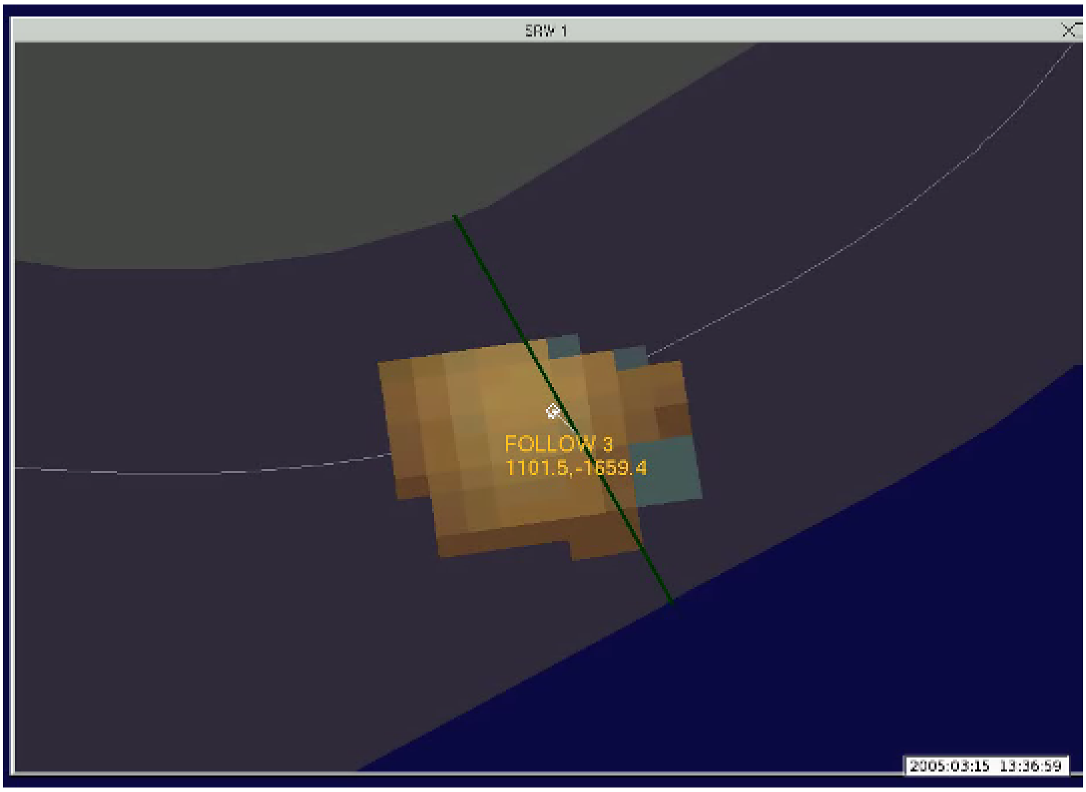


Figure 2-13: Replay Showing Test Vehicle stopped for Static RPA Test

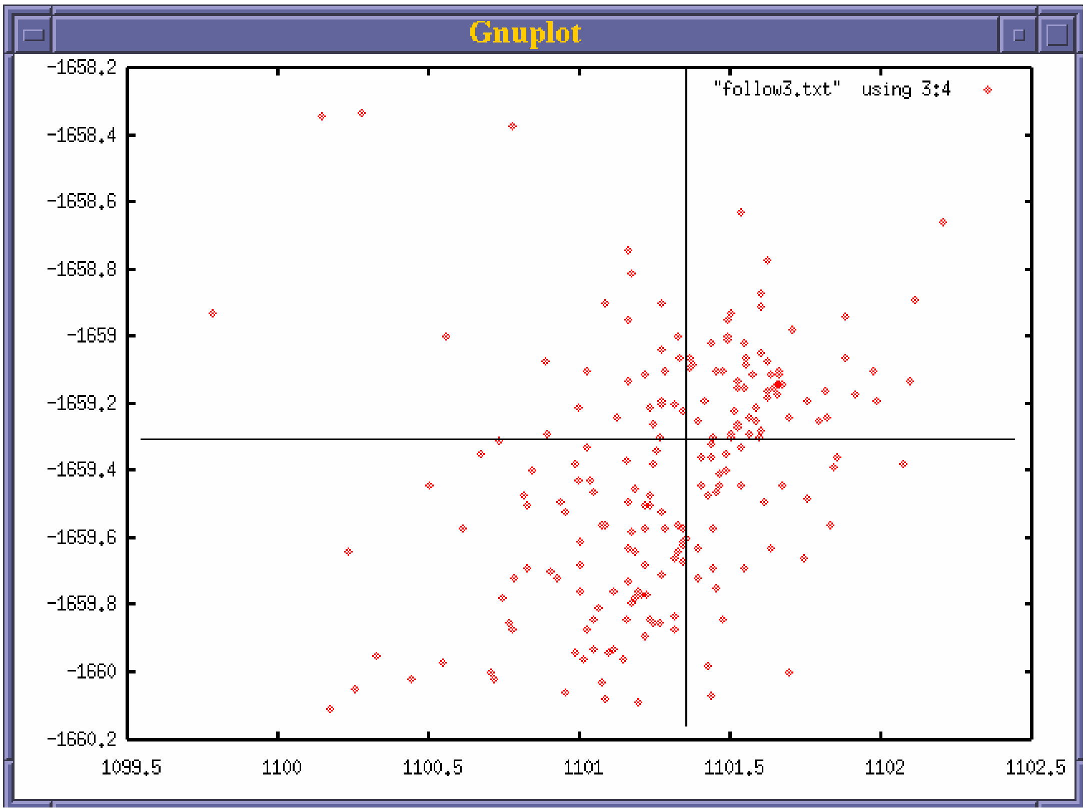


Figure 2-14: Plot Showing Distribution of Reported Position of Stationary Target

b) Dynamic

It was not possible from the recorded data to obtain an objective measurement of the dynamic RPA. As can be seen from the figure below, the target tracks exhibit an overshoot when the target makes a rapid change of direction or speed. The degree of overshoot is proportional to the change of velocity. In order to make a meaningful objective measurement it is necessary to define a standard benchmark test and a desired result. This has not been done in EMMA.

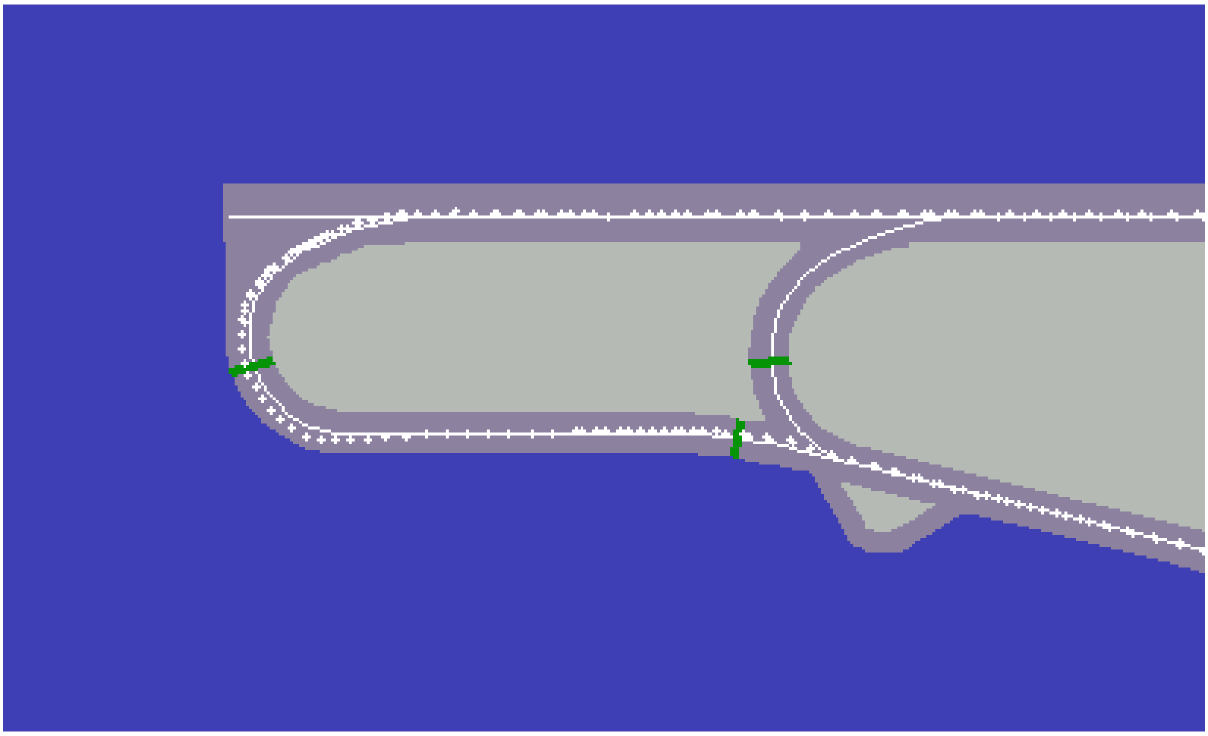


Figure 2-15: Test Vehicle Track showing Overshoot when Cornering

2.3.6 Reported Position Resolution (VE-6)

Hypothesis VE-6	The resolution of the position data in a target report should be better than 1 m.

<u>Test Procedure</u>

The test scenario was the same as for the static RPA test (see VE-5 above).

Playback of the recorded data was used to verify that the smallest change in reported position was less than the specified value.

The target reports from the stationary test vehicle were observed with the CWP set to the lowest range scale, which is 50 m (corresponding to approximately 0.1 m per pixel on the screen). The smallest change in reported position was measured.

<u>Result</u>

The smallest observable change was 1 pixel, corresponding to 0.1m on the 50m-range scale.

2.3.7 Reported Position Discrimination (VE-7)

Hypothesis VE-7	It should be possible to discriminate closely spaced targets, if they are separated by more than the specified performance value. NOTE: 1) Only relevant when one of the targets is non-cooperative. 2) The value has not been specified

Test Procedure

Position a non-cooperative vehicle or obstacle at a known position. Move another non-cooperative vehicle from a distance greater than 100m towards the stationary object. Record the distance at which the Surveillance provides only one Target Report. Move the vehicle away from stationary object and record the distance at which the Surveillance again provides two reports. Conduct the test at least five times. Repeat the test procedure with the following conditions:

- Non-cooperative with cooperative mobile
- Different areas of the aerodrome

The Reported Position Discrimination (RPD) is the worst-case result from all areas per mobile combination.

Result

This test was not carried out at Prague, since the indicator was defined after the SAT. There was not sufficient data recorded during the SAT test period to infer a result.

2.3.8 Reported Velocity Accuracy (VE-8)

Hypothesis VE-8	The accuracy of the target speed data transmitted from the SDS to clients should be better than 5m/s at a confidence level of 95%. The accuracy of the direction of movement data transmitted from the SDS to clients should be better than 10° at a confidence level of 95%.

Test Procedure

The test vehicle FOLLOW3 was driven at a constant speed along the runway and straight stretches of taxiway and the target reports were recorded for at least 50 updates. This test was done in three different areas of the airport and at three different speeds.

Weather conditions at the time of the test were noted.

During playback, the HMI was configured to show the velocity vector and a label with speed and heading for each update.

From the recorded data, the 95% Reported Velocity Accuracy (RVA) was calculated according to EUROCAE guidelines as follows:

For each target report the errors in the speed, Δs, and in the heading, $\Delta\varphi$, were calculated:

Δs = (Known speed - Reported speed) in m/s

$\Delta\varphi$ = (Known heading - Reported heading) in degrees

The resulting data was used to calculate the mean speed and heading errors according to the following formulae, where i = 1,2,3,…n and n is the number of reports:

Mean deviation in speed, $m_s = \sum \Delta s_i / n$

Mean deviation in heading, $m_\varphi = \sum \Delta \varphi_i / n$

Then, the RVA was calculated using the following formulae:

$RVA_s = C^*\sqrt{(\sum (\Delta s_i - m_s)^2/n)} + m_s$

$RVA_\varphi = C^*\sqrt{(\sum (\Delta \varphi_I - m_\varphi)^2/n)} + m_\varphi$

where the coefficient C is set to 1.960 for the required 95% confidence level.

Result

Weather condition: Fine and clear, no precipitation.

Known Speed m/s	n	m_s	RVA_s m/s	m_φ	RVA_φ degrees
4.2	40	-0.003	0.6	0.351	7.9
9.7	71	0.04	0.8	-1.18	4.9
25.8	240	-0.002	1.2	1.12	2.4

Table 2-6: RVA Test Result

2.3.9 Probability of Identification (VE-9)

Hypothesis VE-9	The probability that the correct identity of an aircraft, vehicle or object[1] is reported at the output of the SDF should be 99.9% at minimum.

Test Procedure

a) Short-Term Test (performed at SAT)

The test scenario was the same as for the CV test (see VE-1 above).

More than six thousand target reports were analysed from the recorded data. The targets used for the analysis were the test vehicle and identifiable aircraft moving on the aerodrome Movement Area. The criterion for determining that an aircraft was an identifiable target was that target reports were received from the MLAT system. The criteria for correct identification were that:

- The target report for the test vehicle contained the identifier FOLLOW3; and
- The target report for an aircraft contained the ICAO Aircraft Identification (Callsign) as entered in the flight plan.

From the recorded data, the Probability of Identification (PID) was calculated according to EUROCAE guidelines as follows:

[1] Assuming that the object is identifiable, i.e. suitably equipped and cooperating.

$$PID = \frac{Number\ of\ target\ reports\ with\ correct\ identification}{Total\ number\ of\ reports\ from\ identifiable\ targets} \cdot 100\%$$

b) Long-Term Test (MOGADOR)

First, the MOGADOR tool was used to calculate the PID for the same data as for the short-term tests. This MOGADOR result was compared with the calculated value to confirm that the MOGADOR was correctly calibrated.

MOGADOR was then used to assess the PID for the longer period (4 weeks).

Result

a) Short-Term Test

Weather condition: Fine and clear, no precipitation.

File: “Follow3.txt” recorded 15 March 2005, starting at 13:30 UTC.

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

Area	Mobile Type	Total No. of Reports	No. of Correctly Identified Reports	PID
RWY	Aircraft	1472	1472	100%
	Test vehicle	251	251	100%
TWY	Aircraft	2830	2822	99.72%
	Test vehicle	1730	1730	100%

Table 2-7: Results of Probability of Identification Test

b) Long-Term Test (MOGADOR)

For the evaluation, three days with good weather-conditions (no snow, no precipitation) and seven days with non-optimal conditions (snow and precipitation) are taken into consideration. The following figures show the results for the PID for the different types of mobiles (All, Aircraft, Vehicle and Unknown) and the three locations Runways, Obstacle Free Zone (OFZ) and Taxiways. The results are grouped by the named weather conditions.

NOTE: There is no identification for Unknown targets, because if a target is identified it is either the identification of an Aircraft or a Vehicle.

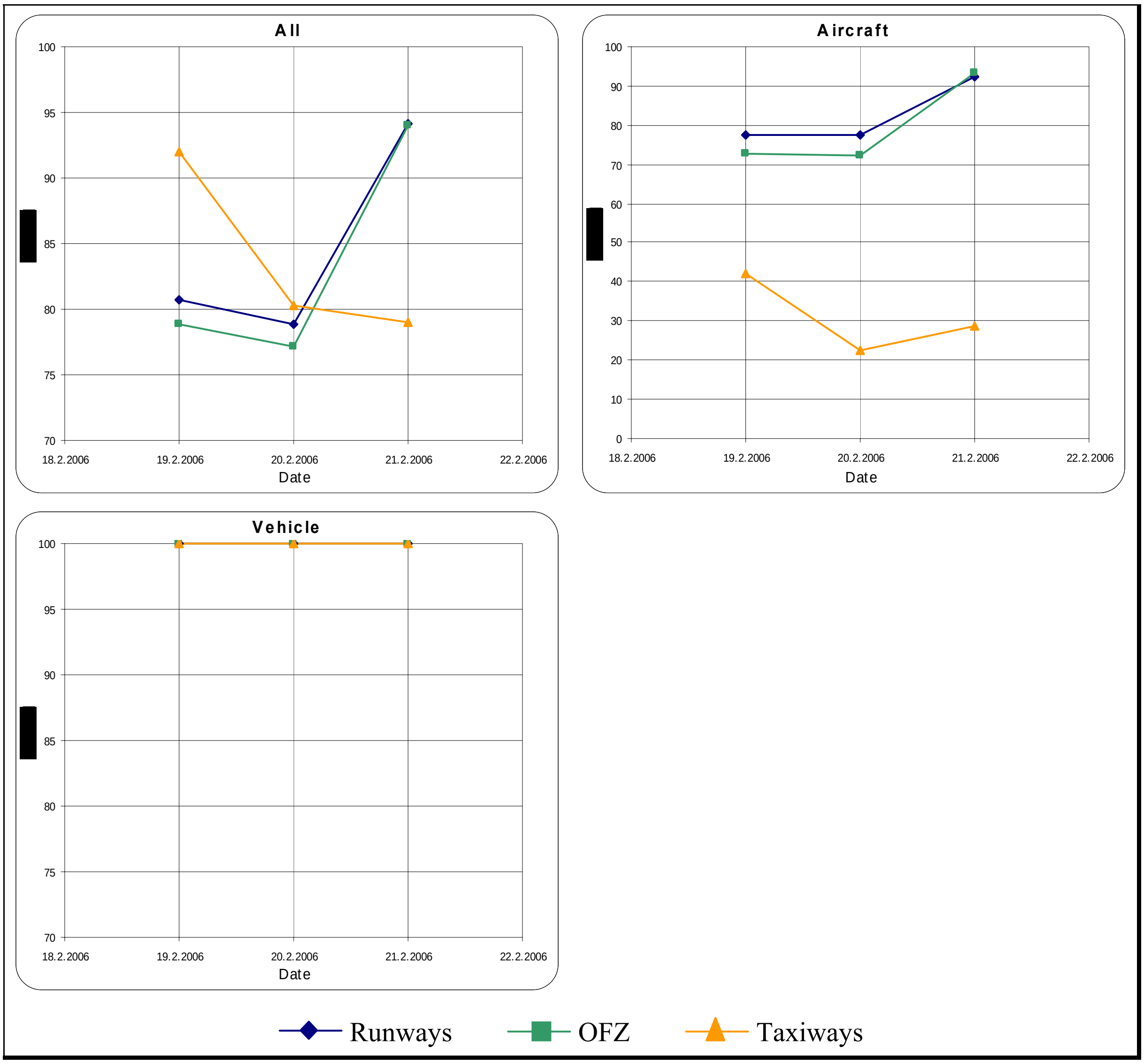


Figure 2-16: PID Long Term Observation (excellent weather conditions (no snow, no precipitation))

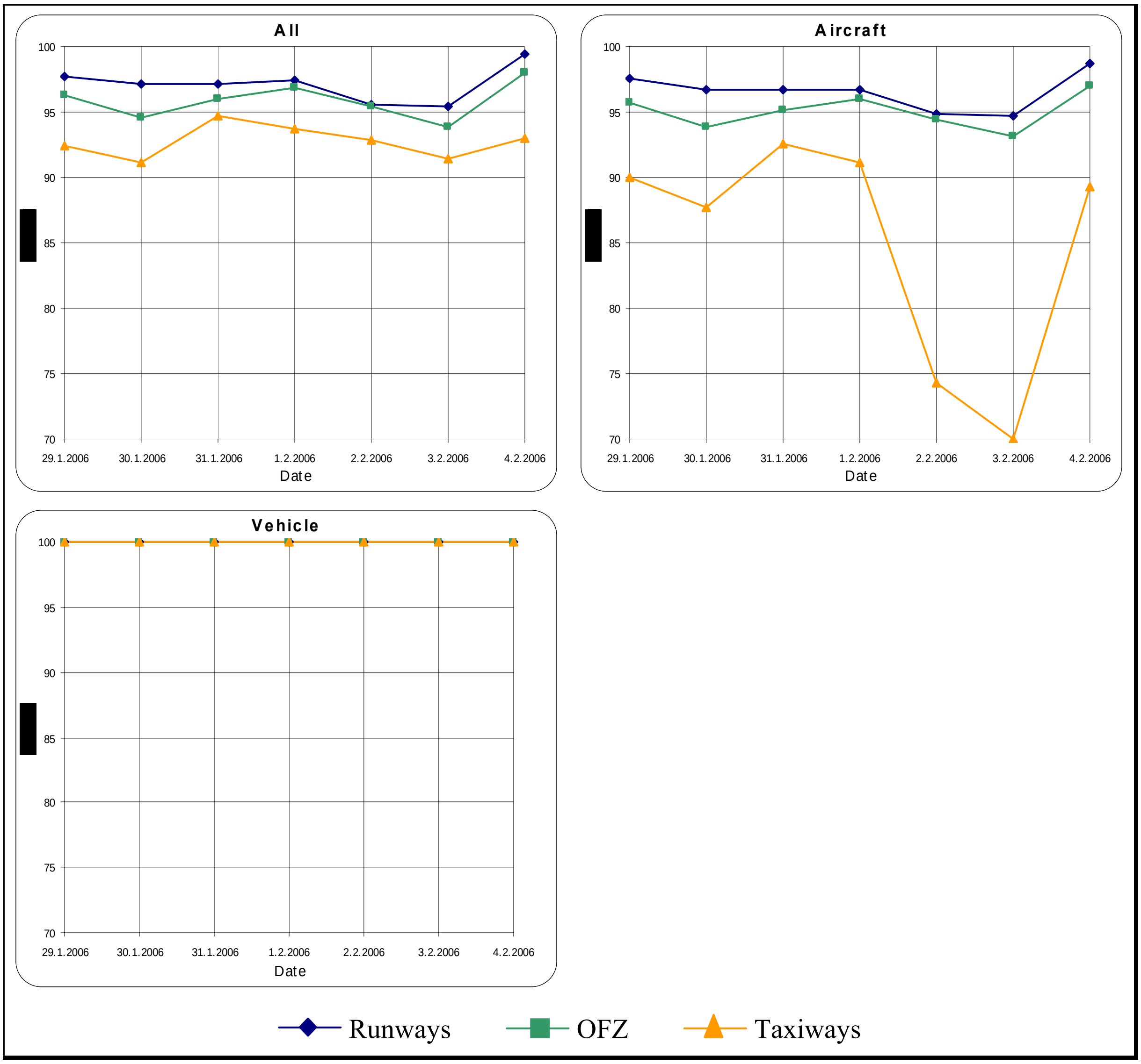


Figure 2-17: PID Long Term Observation (no optimal weather conditions (snow, sunshine))

During the analysis of the PID with MOGADOR it has been discovered that tracks of aircraft are put together with tracks of other aircraft, due to the algorithm of the path-reconstruction-method. The vehicles are not linked with other vehicle or aircraft, because the identification is taken as reliable. Therefore the PID of Vehicle is 100%. The wrong combination of different aircraft is a tuning problem of the evaluation tool and has to be solved in the next version of MOGADOR.

2.3.10 Probability of False Identification (VE-10)

Hypothesis VE-10	The probability that the identity reported at the output of the SDS is not the correct identity of the actual aircraft, vehicle, or object should not exceed 10E-3 per reported target.

Test Procedure

a) Short-Term Test (performed at SAT)

The test scenario was the same as for the CV test (see VE-1 above).

More than six thousand target reports were analysed from the recorded data. The targets used for the analysis were the test vehicle and identifiable aircraft moving on the aerodrome Movement Area. The criteria for correct identification were that:

- The target report for the test vehicle contained an identifier other than the correct identifier FOLLOW3; and
- The target report for an aircraft contained an identifier other than the ICAO Aircraft Identification (Callsign) as entered in the flight plan.

From the recorded data, the Probability of False Identification (PFID) was calculated according to EUROCAE guidelines as follows:

$$PFID = \frac{Number\ of\ target\ reports\ with\ erroneous\ identification}{Total\ number\ of\ target\ reports} \cdot 100\%$$

b) Long-Term Test (MOGADOR)

The test scenario was the same as for the CV test (see VE-1 above).

First, the MOGADOR tool was used to calculate the PFID for the same data as for the short-term tests. This MOGADOR result was compared with the calculated value to confirm that the MOGADOR was correctly calibrated.

MOGADOR was then used to assess the PFID for the longer period (4 weeks).

Result

a) Short-Term Test

Weather condition: Fine and clear, no precipitation.

File: “Follow3.txt” recorded 15 March 2005, starting at 13:30 UTC.

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

Area	Mobile Type	Total No. of Reports	No. of Wrongly Identified Reports	PFID
RWY	Aircraft	1472	0	0.00%
	Test vehicle	251	0	0.00%
TWY	Aircraft	2830	0	0.00%
	Test vehicle	1730	0	0.00%

Table 2-8: Results of Probability of False Identification Test

b) Long-Term Test (MOGADOR)

For the evaluation, three days with good weather-conditions (no snow, no precipitation) and seven days with non-optimal conditions (snow and precipitation) are taken into consideration. The following figures show the results for the PFD for the different types of mobiles (All, Aircraft, Vehicle and Unknown) and the three locations Runways, Obstacle Free Zone (OFZ) and Taxiways. The results are grouped by the named weather conditions.

NOTE: There is no false identification for Unknown targets, because if a target is identified, it is either the identification of an Aircraft or a Vehicle.

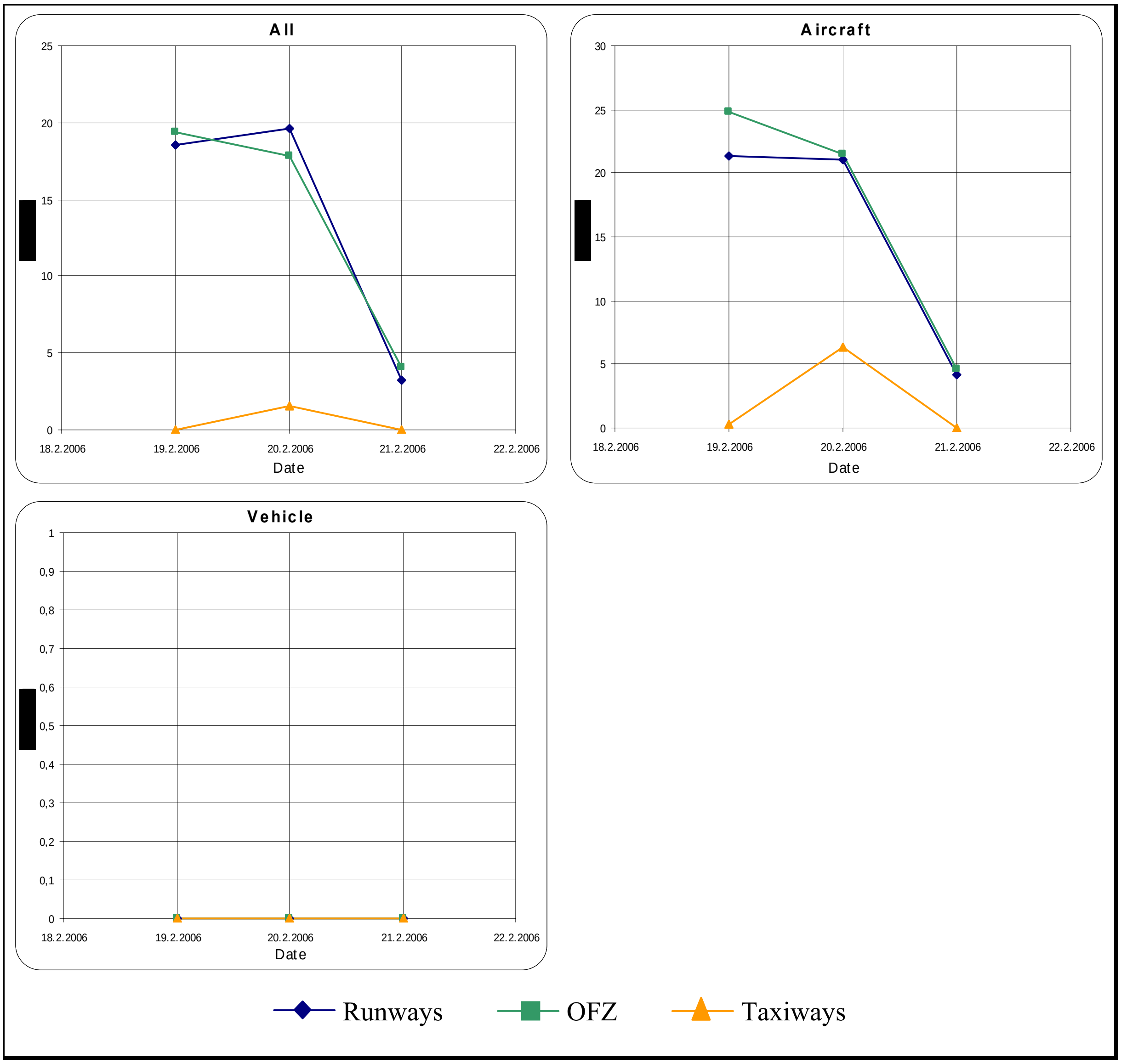


Figure 2-18: PFID Long Term Observation (excellent weather conditions (no snow, no precipitation))

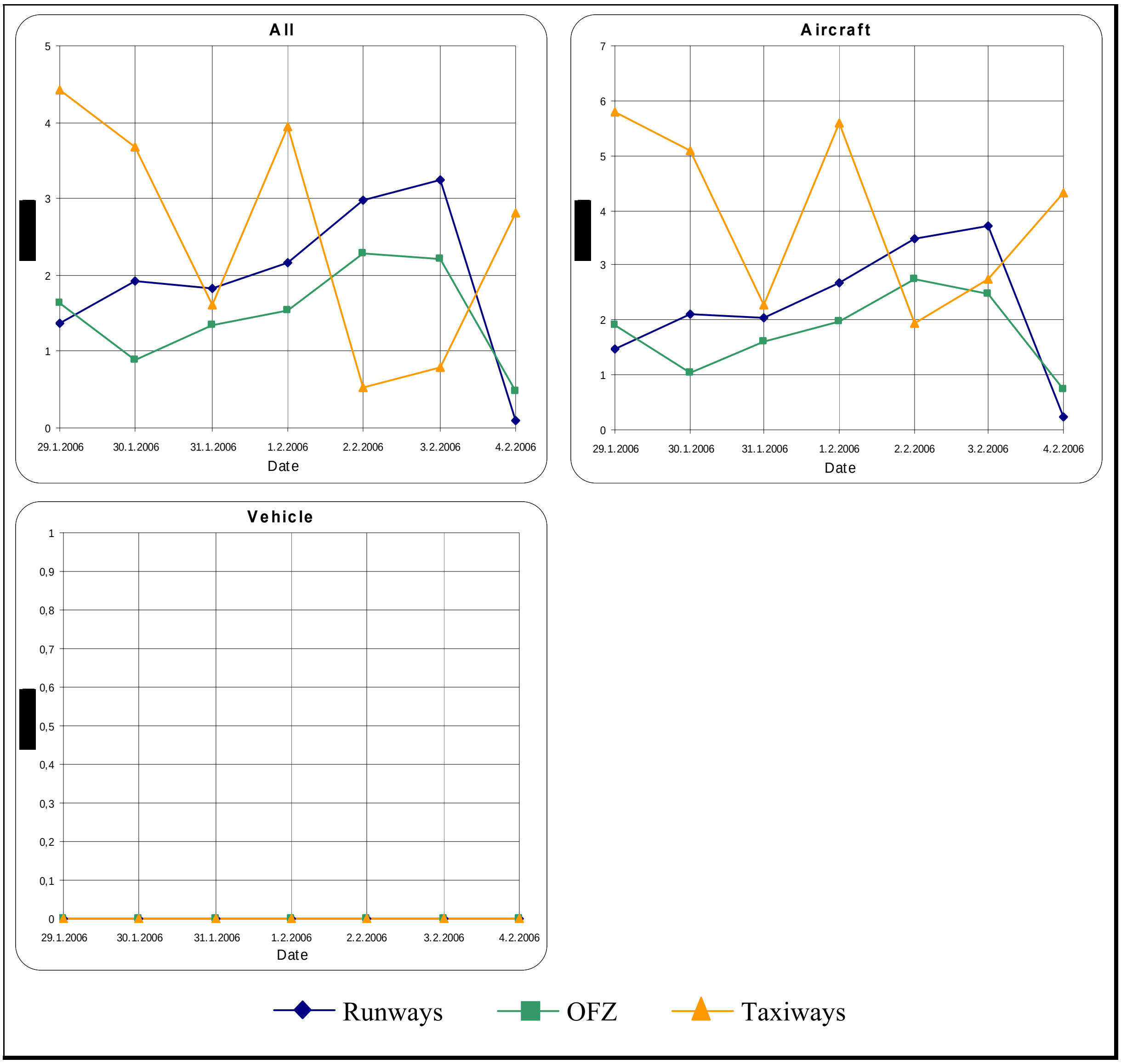


Figure 2-19: PFID Long Term Observation (no optimal weather conditions (snow, sunshine))

During the analysis of PFID with MOGADOR it has been discovered that tracks of aircraft are put together with tracks of other aircraft, due to the algorithm of the path-reconstruction-method. The vehicles are not linked with other vehicle or aircraft, because the identification is taken as reliable. Therefore the PFID of Vehicles is 0%.

The wrong combination of different aircraft is a tuning problem of the evaluation tool and has to be solved in the next version of MOGADOR.

2.3.11 Target Report Update Rate (VE-11)

Hypothesis VE-11	An updated target report should be transmitted from the SDS to the clients at least once per second for each target.

Test Procedure

The test scenario was the same as for the CV test (see VE-1 above).

The traffic situation display on the CWP was observed during a period of heavy traffic to confirm that each target is updated at least once per second.

More than six thousand target reports from the test vehicle and identified aircraft were analysed from the recorded data. These data were used to calculate the average Target Report Update Rate (TRUR) and the distribution.

Result

File: “Follow3.txt” recorded 15 March 2005, starting at 13:30 UTC.

File: “alltracks.txt” recorded 16 March 2005, 10:40 to 11:40 UTC.

No. of Reports	Average TRUR	Variance
6283	0.47 s	0.22 s

Table 2-9: TRUR Test Result

2.3.12 Probability of Detection of an Alert Situation (VE-12)

Hypothesis VE-12	The probability of detection of an alert situation should be greater than 99.9%

Test Procedure

The RIMCAS tool at the CWP-3 (Tower Executive Controller) position was set manually for low visibility conditions. This means that the tool shall generate an alert for the following scenarios:

- An aircraft approaching a runway to land shall generate an alert if another target is detected within the Runway Protected Area and the time to threshold (TTT) is calculated to be less than a pre-defined parameter value. For the Prague tests, this value was set to 45s for Stage 1 (Prediction) and 30s for Stage 2 (Alert) in LVC.
- A landing aircraft shall generate a Stage 2 alert if there is another target detected ahead of it within the Runway Protected Area.
- A departing aircraft that has entered a runway shall generate a Stage 1 alert if there is another target detected within the ground boundary defined by the Runway Protected Area.
- A departing aircraft on a runway shall generate a Stage 2 alert if its speed exceeds a pre-defined parameter value and there is another target detected ahead of it within the Runway Protected Area. For Prague in LVC, the parameter value is set to 20m/s.

The Runway Protected Area was configured as the ground boundary defined by the Cat II / III holding positions for the runway.

This test was conducted during good visibility conditions and during a period of the day with medium to heavy traffic. Two hours of visual observation were used to confirm that the correct alerts were given at the CWP-3 Controller HMI.

For each scenario, it was noted whether the RIMCAS tool gave the correct alert according to the configured rules.

The recorded data was used to calculate the Probability of Detecting an Alert Situation (PDAS) in accordance with the EUROCAE guidelines:

$$PDAS = \frac{Number\ of\ \ correct\ alert\ reports}{Total\ number\ of\ \ actual\ alert\ situations} \cdot 100\%$$

Result

Test performed 10 November 2005, 12:00 UTC to 14:00 UTC.

Weather condition: Fine and clear, no precipitation.

With the chosen set-up, there were alerts for every arriving and departing aircraft since mobiles entering the runways used the CAT I holding positions but the EMMA system was configured for low visibility conditions. Under these conditions, a mobile crossing the CAT II/III hold line should generate an alert if the runway is occupied by an arriving or departing aircraft.

Alert Type	Total No. of Alert Situations	No. of Correct Alert Reports	PDAS
Arrival, Stage 1	12	12	100%
Arrival, Stage 2	12	12	100%
Departure, Stage 1	27	27	100%
Departure, Stage 2	2	2	100%

Table 2-10: Probability of Detecting an Alert Situation

2.3.13 Probability of False Alert (VE-13)

Hypothesis VE-13	The probability of false alert should be less than 10E-3

Test Procedure

The test procedure was the same as for the PDAS test (see VE-12 above).

For each scenario, it was noted whether the RIMCAS tool gave an incorrect (false) alert according to the configured rules.

The recorded data was used to calculate the Probability of False Alert (PFA) in accordance with the EUROCAE guidelines:

$$PFA = \frac{Number\ of\ \ false\ alerts}{Total\ number\ of\ \ aircraft\ movements}$$

Result

Test performed 10 November 2005, 12:00 UTC to 14:00 UTC.

Weather condition: Fine and clear, no precipitation.

There were no false alerts during the period of the test. However, the test period was not sufficiently long for this to be meaningful result for the value of the PFA indicator. Therefore, this indicator was evaluated during the operational on-site trials. Refer to Chapter 6 for the results of the operational tests.

2.3.14 Alert Response Time (VE-14)

Hypothesis VE-14	Having received the target report from the surveillance element, the time taken for the Control function to detect and report any alert situation should be not more than 0.5 s.

Test Procedure

The test procedure was the same as for the PDAS test (see VE-12 above).

Whenever an alert situation occurred, the time (t1) at which the conflict situation was created by a mobile crossing the ground boundary and the time (t2) at which the alert report was given at the CWP was estimated and noted. Since no special tools were available, only a rough estimation was possible.

The Alert Response Time (ART) was calculated in accordance with the EUROCAE guidelines:

$$ART = \sum_{i-1}^{n} \frac{(t2 - t1)_i}{n}$$

Result

Test performed 10 November 2005, 12:00 UTC to 14:00 UTC.

Weather condition: Fine and clear, no precipitation.

Twelve alert situations were used for the analysis.

No. of Alert Situations	ART
12	< 0,5 s

Table 2-11: Result of ART Test

2.3.15 Routing Process Time (VE-15)

Not applicable for Prague.

2.3.16 Probability of Continuous Track (VE-16)

VE-16	Each target track should be continuously updated with a new position report at the nominal update rate of the system throughout the Movement.

Test Procedure

The Mogador tool was used to determine the Probability of Continuous Track (PCT). Gaps (i.e. missing position reports) in each target track were counted and a table was filled out.

From the tables, the MOGADOR tool calculated the value of the PCT.

Result

In the table below, the size of a gap corresponds to the number of missing target reports for that gap. Only tracks corresponding to a wanted target are taken into consideration. Gaps do not include coasted targets.

Size of Gap	1	2	3	4	5	>5
No. of Occurrences of that Gap	44876	1277	399	198	111	1361

Table 2-12: Results of Track Continuity Test (excellent weather conditions (no snow, no precipitation))

Size of Gap	1	2	3	4	5	>5
No. of Occurrences of that Gap	9596	1333	523	213	136	1136

Table 2-13: Results of Track Continuity Test (no optimal weather conditions (snow, sunshine))

As in the last sections with detection and identification, three days with good weather-conditions (no snow, no precipitation) and seven days with no optimal conditions (snow and precipitation) are taken into consideration.

2.3.17 Matrix of Detection (VE17)

The matrix of detection is a table, which is used to assess the distribution of detection losses, according to their frequency and duration. It complements the PCT.

Test Procedure

Gaps (i.e. missing position reports) were counted for every valid track. Then, the duration of each gap was measured. These values were transformed to the occurrence percentage per flight and filled out a table as shown below.

As in the last chapters with detection and identification, three days with good weather-conditions (no snow, no precipitation) and seven days with no optimal conditions (snow and/or precipitation) are taken into consideration. The two tables show the percentage of gaps per day for the two periods.

The table is arranged so that the least interrupted tracks are displayed near the upper-left corner, and the most interrupted are displayed near the lower-right corner.

Results

The total number of valid tracks for the computation of percentages for theMatrix of Detection (good weather) was 11651.

All movements (%)		Duration of Gaps (number of missing reports) 1s	2s	3s	4s	5s	>5s	Total
Number of gaps of a valid track	**0**	47,06						47,06
	1	5,57	1,27	0,51	0,54	0,27	8,18	16,34
	2	1,87	0,50	0,25	0,32	0,18	4,21	7,32
	3	1,14	0,30	0,17	0,17	0,11	2,94	4,84
	4	0,80	0,22	0,09	0,07	0,04	2,02	3,24
	5	0,51	0,17	0,07	0,04	0,04	1,15	1,99
	>5	7,75	3,31	1,58	0,53	0,26	5,78	19,21
	Total	17,65	5,78	2,67	1,67	0,90	24,27	100,00

Table 2-14: Matrix of Detection for all Movements with Good Weather Conditions (no snow, no precipitation) [%]

The total number of valid tracks for the computation of percentages for theMatrix of Detection (adverse weather) was 21263.

All movements (%)		Duration of Gaps (number of missing reports) 1s	2s	3s	4s	5s	>5s	Total
Number of gaps of a valid track	**0**	40,73						40,73
	1	8,18	2,69	1,08	0,43	0,14	4,65	17,18
	2	3,55	1,71	0,91	0,40	0,16	3,11	9,83
	3	2,02	1,36	0,60	0,33	0,10	2,45	6,87
	4	1,02	0,94	0,53	0,27	0,09	2,02	4,87
	5	0,73	0,69	0,37	0,26	0,06	1,69	3,80
	>5	1,97	2,59	2,22	1,30	0,37	8,28	16,72
	Total	17,48	9,99	5,70	2,99	0,91	22,21	100,00

Table 2-15: Matrix of Detection for all Movements with Adverse Weather Conditions (snow or/and precipitation) [%]

2.3.18 Matrix of Identification (VE-18)

The matrix of identification is a table, which is used to assess the distribution of identification losses and erroneous identifications, according to their frequency and duration. This metric is not related to a performance requirement but has a describing character.

Test Procedure

Gaps in correct identification were counted for every valid track. Then, the duration of each gap was measured. These values were transformed to the occurrence percentage per flight and used to fill out a table as shown below.

Two types of matrix were created, in order to assess the probability of the occurrence of:

- Missing identification
- Wrong identification

In addition to that, it can also be distinguished between the following:

- Missing identification with valid mode A codes
- Missing identification with erroneous mode A codes
- Missing identification with missing mode A codes

However, these data are not reported here because they are mainly used to investigate the reasons for missing or wrong identification and are of less operational significance.

Result

The complete number of valid tracks for the computation of the Matrices of Identification was 11651.

There are only three days with good weather-conditions (no snow, no precipitation) taken into consideration. The reason for that was that the Identification is only depending on the MLAT and the Flight –Plan Data, which are independent from the weather. The two tables show the occurrence of gaps for Missing identification and False identification.

Long-Term Test (MOGADOR):

		Duration of Gaps (number of missing identifiers)						
	All (%)	1s	2s	3s	4s	5s	>5s	Total
Number of gaps of a valid track	0	72,90						72,90
	1	1,24	0,50	1,44	1,42	1,18	8,70	14,47
	2	0,15	0,29	0,58	0,48	0,29	4,22	6,01
	3	0,03	0,07	0,08	0,18	0,14	1,90	2,39
	4	0,02	0,01	0,03	0,05	0,10	0,88	1,10
	5	0,01	0,01	0,02	0,02	0,03	0,67	0,75
	>5	0,00	0,01	0,03	0,05	0,05	2,24	2,38
	Total	1,44	0,88	2,17	2,20	1,79	18,62	100,00

Table 2-16: Missing Identification Gap Distribution (Missing label)

		Duration of Gaps (number of false identifiers)						
	All (%)	1s	2s	3s	4s	5s	>5s	Total
Number of gaps of a valid track	0	97,45						97,45
	1	0,15	0,01	0,01	0,02	0,02	0,62	0,82
	2	0,03	0,01	0,04	0,03	0,01	0,41	0,52
	3	0,00	0,00	0,00	0,00	0,01	0,21	0,21
	4	0,00	0,00	0,00	0,01	0,00	0,22	0,23
	5	0,00	0,00	0,00	0,00	0,00	0,09	0,09
	>5	0,00	0,01	0,03	0,00	0,02	0,62	0,68
	Total	0,17	0,03	0,09	0,05	0,05	2,16	100,00

Table 2-17: Wrong Identification Gap Distribution (Wrong label)

2.4 Summary of Technical Results

The table below summarises the results for all measured individual verification metrics.

ID	Indicator	Acronym	Requirement	Measured Value	
				Short-Term	Long-Term
VE-1	Coverage Volume	CV	Approaches Manoeuvring Area Apron taxi lines	√ √ √	n.a.
VE-2	Probability of Detection	PD	≥ 99.9%	99.65%	97,1 – 99,4%
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 confidence 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 Discrimination	RPD	Not defined	Not tested	n.a.
VE-8	Reported Velocity Accuracy	RVA	Speed: ≤ 5 m/s Direction: ≤ 10° at a confidence level of 95%	1.2 m/s 7.9°	n.a.
VE-9	Probability of Identification	PID	≥ 99.9% for identifiable Targets	99.72%	78,8 – 94,1%
VE-10	Probability of False Identification	PFID	< 10E-3 per Reported Target	0.00%	3,2 – 19,7%
VE-11	Target Report Update Rate	TRUR	≤ 1 s	0.47 s	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 Continuous Track	PCT	Not specified	n.a.	See 2.3.16
VE-17	Matrix of Detection	MOD	Not specified	n.a.	See 2.3.17
VE-18	Matrix of Identification	MOI	Not specified	n.a.	See 2.3.18

Table 2-18: Summary of Technical Verification Results

3 Real Time Simulation Results

3.1 Introduction

3.1.1 Participants

A total of 11 ANS-CR controllers in four groups participated in the two phases of the EMMA real time simulations. There were five controllers with the 1st phase and six with the 2nd RTS phase.

Controllers of the first phase were confronted with conflict scenarios to test operational feasibility and operational improvements of the A-SMGCS conflict alert service. Controllers of the second RTS phase did also use the conflict alert service but the traffic scenarios went without evoked conflicts. Separated from the experimental RTS 2 exercises controllers of the 3rd and 4th group (RTS2) were requested to perform a test run using electronic flight stripes and a departure manager and to give their comments to this new A-SMGCS service (cf. 3.4).

All participants were male. The table below outlines the distribution of the controllers to the RTS phases.

Subject	Sex	RTS phase	Conflict scenarios	Groups
C1	M	1	X	1st group
C2	M	1	X	
C3	M	1	X	
C4	M	1	X	2nd group
C5	M	1	X	
C6	M	2		3rd group
C7	M	2		
C8	M	2		
C9	M	2		4th group
C10	M	2		
C11	M	2		

Table 3-1: Allocation of Controllers to the Groups and RTS Phases

3.1.2 Experimental Design

The experimental design is based on the use of real experiments. In real experiments, the same scenarios are used for the *Baseline* System and the *A-SMGCS* set-up in order to achieve ceteris paribus conditions. In this way, results from the *Baseline* system can be directly compared with the *A-SMGCS* within a traffic scenario. However, a comparison of traffic characteristics between the traffic scenarios is lacking the different amount of traffic and runway configurations because Prague regulations do allow only low or medium traffic and runway 24 operations with CATII/III conditions in low visibility. Scenario A and B uses other runway configurations and more traffic volume because the operate with VIS2 and VIS1 conditions respectively.

In conclusion, the following matrix shows the experiment set-up in terms of experimental factors:

	SYS 1 SMGCS (Baseline)	SYS 2 A-SMGCS Level II
VIS 1 (scenario B)	X	X
VIS 2 (scenario A)	X	X
VIS 3 (scenario C)	X	X

Table 3-2: Combination of Experimental Factors

As already mentioned above, emphasis has been put on realistic traffic scenarios to measure the potential influence of using an A-SMGCS at Prague Airport. Realistic scenarios go with realistic traffic amounts in accordance to the visibility conditions, which comply with the local CAT II/III regulation. This mixture of traffic amount and visibility prevents an objective comparison of operational improvements between visibility conditions. However, comparison between A-SMGCS and Baseline are the most wanted and reveal significant operational improvements. The following table shows the details of the traffic used scenarios.

	Scenario A	Scenario B	Scenario C
QFU	↑24 ↓31	↑06 ↓13	↑24 ↓24
APP	ILS CAT I	VOR/DME	ILS CAT II/III
Weather conditions	Day (night?) 350/10 2km visibility (VIS2)	Day 130/15 5km visibility (VIS1)	Day VRB/2 RVR 400m visibility (VIS3)
Timing	~ 60’	~ 60’	~ 60’
Movements	~ 35	~ 41	~ 25
Constraints	TWY RR U/S	RWY 04/22 U/S TWY A, B U/S ILS 06 U/S ALS 06 U/S	NIL
Allowed TFC	↑24 ↓31 (↓24 + ↑31 on request)	↑06 ↓13 (↑13 on request)	↑24 ↓24
Possible conflicts or malfunctions[2]	↓31 x ↑24 ↓31 x ↓24 ↑31 x ↓24 ↓̲24 x ↑31 ↑31 x ↑24 ↑̲31 x ↓31 ↑̲24 x ↓24 ↑̲31 x ↑31 ↑̲24 x ↑24 Wrong label Label lost Wrong direction	↑06 x ↑06 ↓13 x ↓13 ↓13 x ↑06 ↓13 x ↑̲06 ↓13 x ↑13 ↓13 x ↑̲13 ↑̲06 x ↑06 ↑̲13 x ↑13 Wrong label Label lost Wrong direction	↓24 x ↓24 ↓24 x ↑24 ↑̲24 x ↑24 Wrong label Label lost Wrong direction
Conflicts or malfunctions of interest[3]	↓31 x ↑24 ↓31 x ↓24 ↓̲24 x ↑31 ↑31 x ↑24 Wrong direction	↑06 x ↑06 ↓13 x ↓13 ↓13 x ↑06 ↓13 x ↑̲06 ↓13 x ↑13	↓24 x ↓24 ↓24 x ↑24 ↑̲24 x ↑24 Wrong label Label lost

Symbol convention:

↓	Conflicting aircraft during approach, landing or landing roll
↓̲	Conflicting aircraft after landing during taxiing (e.g. RWY crossing)
↑	Conflicting aircraft during take-off run, take-off or initial climb out
↑̲	Conflicting aircraft before take-off during taxiing (e.g. holding point for same or crossing RWY crossed etc.)
↓24	Conflicting aircraft for RWY 24
x	Versus (e.g. ↓24 x ↑24)

Table 3-3: RTS Traffic Scenario Description

[2] only with RTS 1
[3] only with RTS 1

3.1.3 Experimental Course

With the test plan, it was aimed to completely randomise all experimental condition to retain the best test power. However, due to technical problems and lacking availability of controllers this aim could not be fully achieved. With the first group, traffic scenario A had technical malfunctions. The second group lacked the 3rd controller, so that the TPC position had to be abandoned. The 3rd and 4th groups were affected by less available test days so that a full randomisation could not be achieved. However, the final distribution of the controllers to the CWP, scenarios and system conditions is sufficient to derive meaningful test results.

	Scenario A						Scenario B						Scenario C					
	A-SMGCS			Baseline			A-SMGCS			Baseline			A-SMGCS			Baseline		
	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC
C1							X	X	X	X	X	X	X	X	X	X	X	X
C2							X	X	X	X	X	X	X	X	X	X	X	X
C3							X	X	X	X	X	X	X	X	X	X	X	X
C4		X	X		X	X		X	X		X	X		X	X		X	X
C5		X	X		X	X		X	X		X	X		X	X		X	X
C6		X			X				X			X	X			X		
C7	X			X				X			X				X			X
C8			X			X	X							X			X	
C9		X			X				X			X	X			X		
C10	X			X				X			X				X			X
C11			X			X	X			X				X			X	

Table 3-4: Distribution of the Controllers to the Test Conditions

The Real-Time Simulation used the Real-time Tower Simulator at DLR-Braunschweig. The Validation Platform is described in the EMMA Prague test plan [13].

Within this document and with all Prague test trials, the term "A-SMGCS" includes the following services:

- At **A-SMGCS Level I**, additional surveillance information from the data fusion of cooperative and non-cooperative surveillance sensors provides a seamless coverage of the entire Movement Area. Controllers are provided with a labelled Traffic Situation Display.
- **A-SMGCS Level II** complements the A-SMGCS Level I Surveillance Service with a Control Service, the objective of which is to detect potentially dangerous conflicts in order to improve safety of runways and restricted areas. Controllers are provided with an automated system function (RIMCAS) for detecting and alerting them of potential conflicts.

3.1.4 Technical and Operational approval of the RTS

To assure that the implemented A-SMGCS works properly and to assure that the traffic scenarios are operational usable, a technician and a separate controller checked whether the A-SMGCS had been implemented correctly and that all functions worked properly before starting the operational trials.

Operational Considerations

From an operational point of view, it has to be concluded that the testing of operational improvements (safety, efficiency, etc.) was influenced by testing of the operational feasibility of the monitoring and alerting service with the 1st phase of RTS trials. Several conflict situations had been revealed by the pseudo-pilot that were needed to test the controllers' reaction time and their acceptance, but also influenced the normal controllers' behaviour. With the 2nd RTS, conflict situations were not further induced in order to measure operational improvements without impact of non-nominal events.

Technical Drawbacks that could not be solved for RTS I:

- RWY Stop bar alert in CATII/III did not work
- Restricted area alert did not work
- "Wrong direction take off" was not established
- No extended label – only call-sign in it
- Vis2 and Vis3 outside view could be lower
- No manual labelling possible
- Label colour of cars was not brown (as desired) but white (same as departure, as cars had to be defined as aircraft in the simulation scenario)
- Pseudo-pilots could not stop the aircraft in time when needed
- T2 alerts with RWY13 arrivals and stopped traffic on TWY F
- Permanent T1 (amber) alert on TWY F between TWY D and RWY31/13
- Sensitive area is too long on TWY F between TWY D and RWY31/13 with Crossing traffic on RWY31/13
- No text in label – several times
- Missing label with arrivals on RWY13 between threshold and intersection to TWY F
- With setting the "Suppression" Area 2, labels on Apron North disappear (as wanted) but also with vacating traffic from RWY13
- No editing possible
- Sometimes orange T1 alert with acoustic warnings, which is wrong
- Car alone on TWY F and orange T1 alert, which is wrong.

3.2 Operational Feasibility (RTS)

3.2.1 Acceptance questionnaire results

Each of the 11 ANS_CR Controllers was given a 30 items acceptance questionnaire after finishing all test runs. They were asked to give their opinion to the use of A-SMGCS. The answering scale reached from 1 "Strongly disagree" to 10 "Strongly agree". The following general hypothesis was set up to describe the expectation with the controllers' answers:

Identifier	Hypothesis
OF-H0	The controllers' opinion does not agree to the "operational feasibility" aspects of a specific item.
OF-H1	The controllers' opinion agrees to the "operational feasibility" aspects of a specific item.

11 x 30 answers were achieved that are summed up with the following table:

	Item No.																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C1	8	4	10	8	1	1	8	3	9	10	5	8	9	3	8	8	9	9	8	8	9	7	8	8	3	9	8	8	6	7
C2	9	3	9	8	3	1	9	2	8	9	5	9	9	2	9	8	8	9	6	10	8	7	8	9	6	9	9	7	3	8
C3	8	2	8	9	2	1	10	3	9	8	6	7	8	3	7	8	9	9	8	7	7	7	9	8	6	9	7	6	6	7
C4	8	4	8	7	2	1	10	3	9	9	6	8	9	3	7	8	8	8	7	8	8	9	8	8	4	9	8	7	5	7
C5	8	2	10	7	3	1	9	1	8	9	6	8	8	3	9	8	7	9	8	7	6	9	10	9	3	8	6	9	4	8
C6	9	3	10	8	1	1	8	3	8	9	6	8	9	3	9	7	8	9	8	8	7	9	9	9	3	8	9	6	4	9
C7	9	4	6	9	1	1	9	1	9	9	8	7	8	3	8	9	7	8	8	10	8	8	8	8	3	9	8	6	6	9
C8	8	3	9	9	1	2	8	4	9	10	5	8	9	4	8	9	7	8	8	10	9	7	8	9	4	9	7	7	4	9
C9	9	4	6	7	1	2	8	4	9	8	8	7	8	2	9	7	9	8	7	7	8	9	9	9	4	9	7	7	4	8
C10	7	3	6	8	3	2	10	1	9	8	7	7	8	3	7	9	8	8	8	7	7	7	8	8	6	8	7	8	5	9
C11	9	3	6	9	3	1	8	2	8	10	6	8	8	3	9	9	9	8	8	8	6	7	8	9	3	8	7	7	6	8
C = Controller																														

Table 3-5: Raw Data of the RTS Acceptance Questionnaire

By use of a t-test for a single sample size, each item was proved for its statistical significance. Table 3-6 shows the respective results. P-value with a star* indicate its statistical significance.

	Test Value = 5.5		
Item	T	df	p (1-sided)
ITEM01	14,087	10	,000*
ITEM02	-10,241	10	,000*
ITEM03	4,787	10	,001*
ITEM04	10,338	10	,000*
ITEM05	-12,618	10	,000*
ITEM06	-30,016	10	,000*
ITEM07	12,594	10	,000*
ITEM08	-8,953	10	,000
ITEM09	20,618	10	,000*
ITEM10	14,986	10	,000*
ITEM11	2,096	10	,031*
ITEM12	11,423	10	,000*
ITEM13	18,764	10	,000*
ITEM14	-15,932	10	,000*
ITEM15	10,178	10	,000*
ITEM16	11,847	10	,000*
ITEM17	10,338	10	,000*
ITEM18	18,764	10	,000*
ITEM19	10,510	10	,000*
ITEM20	7,113	10	,000*
ITEM21	6,550	10	,000*
ITEM22	7,832	10	,000*
ITEM23	14,252	10	,000*
ITEM24	19,341	10	,000*
ITEM25	-3,594	10	,003*
ITEM26	20,618	10	,000*
ITEM27	7,262	10	,000*
ITEM28	5,590	10	,000*
ITEM29	-2,096	10	,031
ITEM30	10,338	10	,000*

Table 3-6: T-Test for 30 items of the Acceptance questionnaire

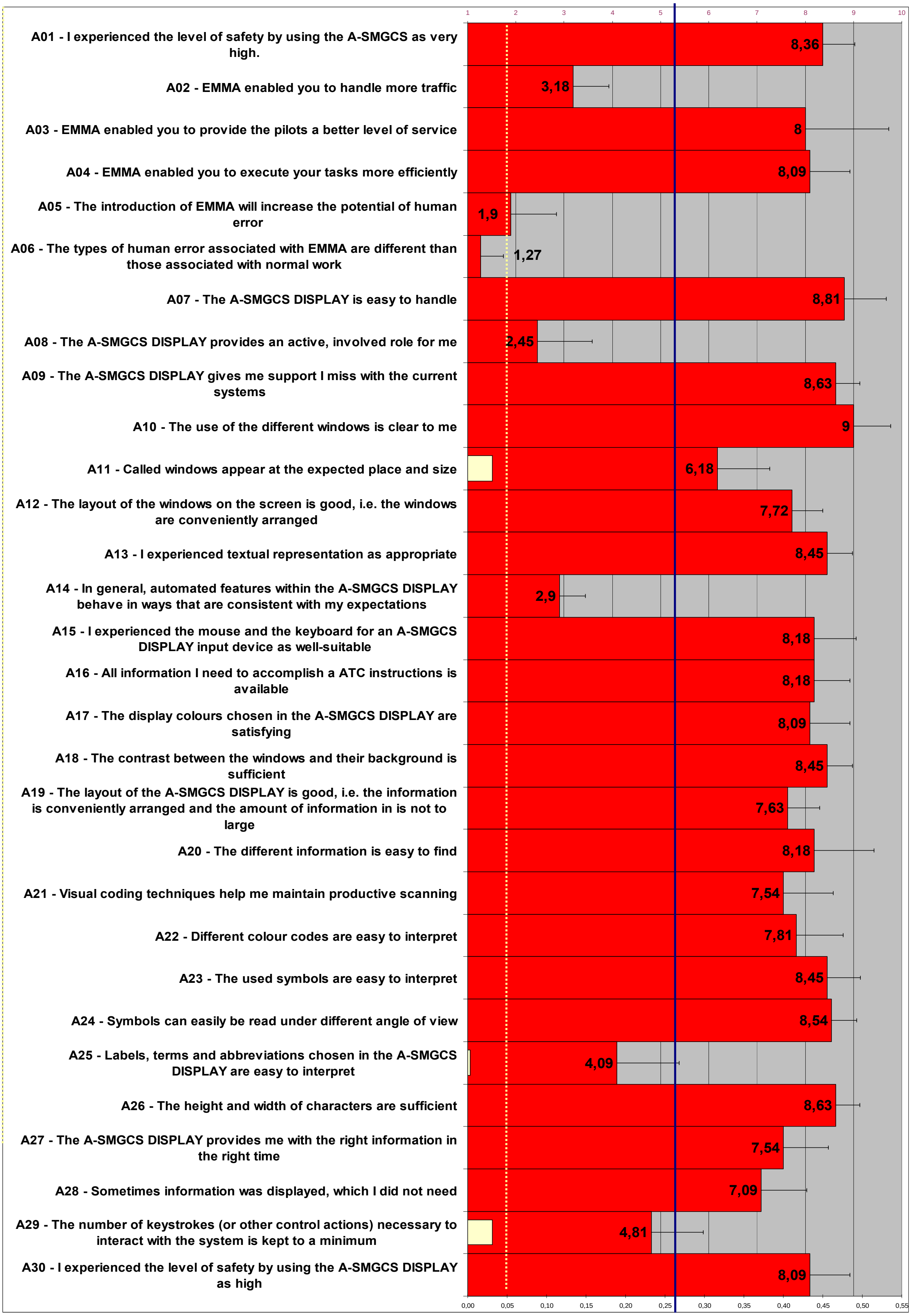


Figure 3-1: Bar Chart for Means, SD, and p-values for 30 items from the RTS Acceptance Questionnaire

The bar chart with Figure 3-1 gives a good overview about the answers to each item. The mean value is 5.5[4], which is represented by the blue line. Except for item 08 and item 29 all statements have been answered towards the expected end of the scale. The p-values are represented by the scale of the lower horizontal axis, the 0.05 yellow line and the yellow bars on top of the red bars. No yellow bar exceeds the critical 0.05% line, which expresses the statistical significance of all items[5].

Concluding Results
28 of 30 acceptance items have been significantly answered by 11 controllers in the expected direction. Therefore, it can be stated that the use of the A-SMGCS in the two RTS phases was of high operational feasibility.

3.2.2 Debriefing Comments

After finishing all test runs, each controller was given the chance to express his general comments, suggestions, and criticisms about the A-SMGCS. The following comments have been highlighted here:

- Immediate T2 alerts with crossing departing or landing aircraft are not desirable for the controllers – amber would be better - or red, when better tuned
- Controllers could imagine a big and separate "resolution button" to tell the automation that the conflict situation is under control or resolved
- One acoustic alert peep would be sufficient to make the controller aware of a conflict
- With the "Time-to-threshold" window, the line 15sec is missing
    - Would also prefer distance instead of time because of the ATC separation rules
    - Time is also advantageous, but more with a smaller scale (perhaps 3 or 5 sec.)
    - Controller 2 prefers to see the timing with "15sec and more", instead of "15sec and less"
- When more than one target on the RWY an orange alert is given, which has been estimated as potentially useful, but:
    - not with diverging targets
    - not with RWY31/13 crossing with TWY F and RWY24/06 (arrivals and departures)
    - not with RWY31/13 crossing with TWY F and RWY13 arrived aircraft that are already behind this crossing area.

[4] The figure's mean line is not exactly 5,5, which resulted from a MS Excel drawback that does not support such a mean line in a proper way.
[5] Except for item 08 and 29 that are answered in the non-expected direction.

3.3 Operational Improvements (RTS)

With the Prague Test Plan [13] high-level and low-level V&V objectives were translated into measurable indicators and measurement instruments. The following table gives an overview about the operational improvements that were intended to be measured with the real-time simulation exercises.

High-level Objective	Low-level Objective	Indicator	Measurement Instruments	Obj./ Sub.
Safety	Reduced number of incidents and accidents	1. Number of incidents and accidents	Observations	Obj.
	Faster identification and mitigation of safety hazards	2. Time for conflict detection, identification, and resolution	Observations	Obj.
Efficiency/ Capacity	Higher maximum number of aircraft handled	1. Number of aircraft handled[6]	Recordings	Obj.
	Lower holding time per aircraft	2. Holding Time[7]	Recordings	Obj.
	Lower Taxi Time for in and outbound traffic	3. Taxi Time	Recordings	Obj.
	Lower duration of radio communications	4. Duration of radio communications (R/T load)	Recordings	Obj.
	Lower number of requests to the pilot to report her/his position	5. Number of requests to the pilot to report her/his position[8]	Observations	Obj.
Human Factors	Higher Situation Awareness	1. Situational Awareness	SASHA_Q SASHA_ on-Line	Sub.
	Convenient level of workload	2. Workload	I.S.A	Sub.

Table 3-7: Low-level Objectives, Indicators, and Measurement Instruments for Measuring operational improvements in the RTS

3.3.1 Safety

3.3.1.1 Number of incidents and accidents

Identifier	Hypothesis
OI-SAF1-H0	There is no difference in terms of **number of incidents** between the Baseline and the A-SMGCS Level II.
OI-SAF1-H1	The **number of incidents** decreases as an effect of introducing the A-SMGCS application and the related procedures.

[6] The "number of aircraft handled by the controllers" was given by the traffic scenario itself. Differences in terms of efficiency can be seen with the "taxi time"
[7] The "holding time" of aircraft during taxiing could not be recorded.
[8] As the surveillance service worked with a 100% performance there was no need for the controller to request a pilot to report her/his position. In the baseline condition in VIS3 procedural control was applied. Differences in terms of efficiency can be seen in the "R/T load".

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

The H0 hypothesis OI-SAF1-H0 could not be rejected with the used experimental design.

3.3.1.2 Reaction Time for Conflict Detection

Identifier	Hypothesis
OI-SAF2-H0	There is no difference in terms of **time between the start of a conflict and resolution of it** by the controllers between the Baseline and the A-SMGCS Level II.
OI-SAF2-H1	The **time between the start of a conflict and resolution of it** by the controllers decreases as an effect of introducing the A-SMGCS application and the related procedures.

The reaction time was measured by an observer who measured the time between the initiation of a conflict and the reaction of a controller. The reaction of a controller was defined by the time when the controller 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, which were outlined in Table 3-3. The kind and number of conflict situations were adapted to the own dynamic of a traffic scenario. That's why the kind and number of conflicts slightly varies between the test runs and scenarios. Therefore, the reaction time was summed up over the scenarios and controllers, but was separately analysed with respect to the controller working positions: TEC and GEC. The TPC was not affected by conflict situations and therefore was not analysed.

The following tables provide the raw data of *reaction time* referred to the TEC and GEC control positions.

A		B		C	
A-SMGCS	Baseline	A-SMGCS	Baseline	A-SMGCS	Baseline
6	12	14	8	13	8
2	5	3	3	2	10
2	7	6	2	3	6
2	4	4	3	10	6
2	4				

Table 3-8: Raw Data for *Conflict Reaction Time* for the TEC Position [sec] (RTS 1 only)

A		B		C	
A-SMGCS	Baseline	A-SMGCS	Baseline	A-SMGCS	Baseline
3	3	2	6	6	4
		3	4	7	7
		2	2	2	2
		3	3	2	3
		15	4	2	4
				2	3
				3	4
				2	5

Table 3-9: Raw Data for *Conflict Reaction Time* for the GEC Position [sec] (RTS 1 only)

The following tables outline the statistical values and the statistical test results. A t-test for paired differences was conducted to prove the data for their statistical significance:

		Mean	N	SD	SE
TEC	A-SMGCS	5,3077	13	4,32791	1,20035
	Baseline	6,0000	13	2,94392	,81650

Table 3-10: Means, SD, and SE for the TEC's Reaction Time (RTS 1 only)

		Mean	N	SD	SE
GEC	A-SMGCS	3,8571	14	3,57033	,95421
	Baseline	3,8571	14	1,40642	,37588

Table 3-11: Means, SD, and SE for the GEC's Reaction Time (RTS 1 only)

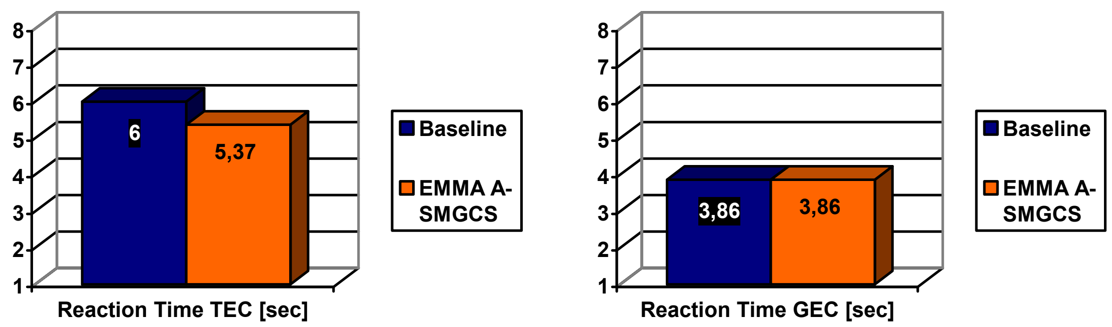


Figure 3-2: Bar Charts of the Mean Reaction Time for TEC and GEC Position (RTS 1 only)

		M	SD	SE	T	df	p-value
TEC	A-SMGCS - Baseline	-0,69231	4,46065	1,23716	-0,560	12	0,30
GEC	A-SMGCS - Baseline	0,00000	3,48624	0,93174	0,00	13	1,000

Table 3-12: T-tests for paired differences: Reaction Time of TEC and GEC position (RTS 1 only)

Concluding Results

The results show no significant differences in the “reaction time” between A-SMGCS and the baseline condition neither for the TEC (M = -0,69 seconds, $T_{(12)}$ = -0,560, p > .05) nor for the GEC position (M = 0,00 seconds, $T_{(13)}$ = 0,00, p > .05). For the TEC position, there is a trend that shows that controllers react faster in the A-SMGCS condition but the effect seems not that high to be proven with only 13 pairs of conflict situation. For the GEC position there was no difference measured.

In addition to that, the test observer reported that reaction times are hard to measure. Particularly, assessing the time when a conflict is initiated or when it can be identified as a potential conflict situation is a rather subjective estimation by the observer. Additional error variance can be assumed with the fact that conflict situations are always slightly different even when they happen at the same time in the same traffic scenario. By so far, the sample size of conflict situations in RTS must be very high to randomise these side effects and to show significant differences. However, the greater the amount of conflict situations the less the naturalness of the traffic scenario.

The H0 hypothesis OI-SAF2-H0 can not be rejected.

3.3.2 Efficiency/Capacity

3.3.2.1 Taxi Time

Identifier	Hypothesis
OI-EFF1-H0	There is no difference in terms of **global taxiing time** between the Baseline and the A-SMGCS Level II.
OI-EFF1-H1	The **global taxiing time** is reduced as an effect of introducing the A-SMGCS Level II application and related procedures.

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 (except of that the callsigns were changed to alleviate recall effects with controllers), pairs of identical taxiing aircraft within identical traffic scenarios could be gained. This guaranteed that measured differences could be claimed for better efficiency of A-SMGCS to reduce the average duration of taxi times.

3.3.2.1.1 Raw Data

Pairs of “taxi times” were summed up for each scenario A, B, and C dependent on in- and outbound traffic, and A-SMGCS vs. Baseline condition. The following raw data were recorded:

Scenario A				Scenario B				Scenario C			
Inbound		Outbound[9]		Inbound		Outbound		Inbound		Outbound	
A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base
179	181			74	454	87	85	334	319	139	172
249	242			111	272	106	89	369	384	256	542
259	251			277	280	230	801	379	271	331	408
300	262			368	370	493	884	385	402	520	812
310	490			380	526	710	743	440	470	564	615
316	163			575	484	748	948	448	490	571	693
332	542			602	507	778	980	522	521	583	583
350	309			606	145	901	778	523	492	583	579
403	367			608	683	979	1090	534	535	649	664
512	501			614	892	987	1103	622	591	679	675
519	549			637	585	1022	1107	155	320	723	848
537	451			684	595	1044	1006	186	134	775	602
575	766			33	629	1089	777	365	386	878	494
621	616			154	665	1102	1237	367	368	83	96
800	796			225	81	1198	1164	398	649	216	399
191	181			492	649	85	113	426	443	323	310
191	509			496	556	96	97	451	708	384	573
260	255			551	504	681	1016	454	492	516	732
280	257			552	129	685	736	579	408	531	571
317	348			561	634	699	838	228	373	572	542
321	375			143	244	821	832	296	321	583	716
327	355			242	350	891	953	342	361	629	829
366	366			274	395	967	1004	414	432	654	700
487	573			288	278	81	90	431	404	691	939
494	470			348	364	100	84	440	553	140	127
509	610			364	234	461	508	499	396	264	240
563	301			369	367	475	921	521	411	348	789
629	719			395	468	624	844	541	691	545	934
692	847			435	622	635	943	619	498	562	443
794	70			457	500	654	732	646	604	586	826
159	160			464	575	727	830	270	245	664	835
179	270			475	516	736	907	370	320	676	1165
184	524			511	562	741	868	381	405	734	736
233	349			513	469	794	796	385	426	772	959
250	279			518	593	847	846	445	466	784	1215
259	401			544	580	847	964	522	546	850	839
306	322			594	603	883	1167	637	522	85	366

[9] Data seemed to be corrupted and did not used for the analysis. Baseline taxi times were much more longer than usual, which were properly caused by a systematic recording failure.

Scenario A				Scenario B				Scenario C			
Inbound		Outbound[9]		Inbound		Outbound		Inbound		Outbound	
A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base
351	334			726	597	959	1107	251	450	228	271
366	94			215	268	991	1135	339	320	314	340
378	569			277	323	1012	1212	381	356	395	366
432	431			369	369	1044	1239	390	385	506	838
488	522			386	369	102	86	398	711	546	615
592	651			417	417	145	96	411	386	561	515
654	744			455	372	211	358	433	462	570	753
				476	594	405	862	438	439	632	640
				476	421	575	1094	501	531	636	666
				476	498	587	970	553	500	658	503
				480	406	601	819	573	591	695	683
				492	102	703	1089	625	745	127	136
				495	438	717	739	636	460	242	583
				510	557	717	754	119	398	331	801
				511	560	827	1174	229	530	507	819
				514	509	847	966	319	331	516	814
				554	555	862	1068	386	386	548	1291
				674	263	871	1620	399	598	573	957
				74	89	897	887	438	465	595	836
				89	584	910	894	504	774	617	757
				92	278	934	1095	514	514	635	852
				129	516	85	110	521	521	790	1159
				217	105	91	97	579	384	1104	1180
				376	571	713	903			119	128
				403	537	727	803			228	487
				433	411	799	984			385	918
				495	603	870	871			525	803
				585	611	882	1068			578	830
						969	1148			609	802
										636	809
										679	754
										763	828
										928	889

Table 3-13: Taxi Time Raw Data [sec] (RTS 1)

Scenario A				Scenario B				Scenario C			
Inbound		Outbound		Inbound		Outbound		Inbound		Outbound	
A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base	A-SMGCS	Base
486	686	793	673	457	399	726	797	540	412	607	607
496	471	862	658	460	463	742	1215	568	540	116	112
499	514	879	594	475	478	744	1073	604	470	352	316
523	476	905	975	483	84	763	867	72	340	406	293
525	641	1026	903	495	480	822	891	170	339	440	527
649	717	1127	1092	525	1317	859	856	336	328	462	659
716	727	129	156	570	595	866	1022	351	391	480	324
833	73	295	73	577	569	999	810	374	524	565	441
934	908	309	528	605	586	67	64	469	455	629	483
94	37	480	427	82	214	82	138	470	410	653	381
168	503	481	482	215	339	392	601	474	1329	709	403
187	192	499	856	234	234	510	581	480	555	714	890
195	180	502	569	247	215	588	781	514	554	728	618
212	158	525	500	397	475	596	807	551	401		
274	307	564	725	403	523	639	1000	561	514		
306	307	610	746	442	407	690	852				
408	288	631	778	445	524	722	967				
413	383	672	430	451	445	768	938				
416	383	689	559	468	470	795	900				
499	493	734	777	495	1401	849	1011				
503	487	964	511	511	492	919	1066				
506	451	1072	625	516	558	1107	782				
530	652			524	541						
554	519			575	593						
626	621			621	595						
841	635			681	710						
841	627										

Table 3-14: Taxi Time Raw Data (RTS 2)

3.3.2.1.2 Results

Scenario	In-or Outbound	A-SMGCS / Baseline	Average Taxi Time (sec)	Difference (sec)	df	t	p-value[10]
A	In	A-SMGCS	398	-19	43	-0.786	0.22
		BASELINE	417				
	Out	A-SMGCS	No valid data				
		BASELINE	No valid data				
B	In	A-SMGCS	414	-37	64	-1.541	0.07
		BASELINE	451				
	Out	A-SMGCS	683	-137	65	-6.370	0.00*
		BASELINE	820				
C	In	A-SMGCS	431	-29	59	-1.941	0.03*
		BASELINE	460				
	Out	A-SMGCS	532	-142	69	-6.351	0.00*
		BASELINE	674				
Total		A-SMGCS	500	-79	304	-7.728	0.00*
		BASELINE	579				

Table 3-15: Taxi Time Results (RTS 1)

Scenario	In-or Outbound	A-SMGCS / Baseline	Average Taxi Time (sec)	Difference (sec)	df	t	p-value[11]
A	In	A-SMGCS	444	21	35	0.820	0.21
		BASELINE	423				
	Out	A-SMGCS	659	30	30	0.795	0.22
		BASELINE	629				
B	In	A-SMGCS	422	-75	34	-1.883	0.03*
		BASELINE	497				
	Out	A-SMGCS	625	-153	30	-4.782	0.00*
		BASELINE	778				
C	In	A-SMGCS	426	-31	23	-0.734	0.24
		BASELINE	457				
	Out	A-SMGCS	478	48	21	1.732	0.05
		BASELINE	430				
Total		A-SMGCS	510	-30	178	-1.973	0.03*
		BASELINE	540				

Table 3-16: Taxi Time Results (RTS 2)

[10] The star with a p-value shows its significance with an $\alpha = 0.05$.
[11] The star with a p-value shows its significance with an $\alpha = 0.05$.

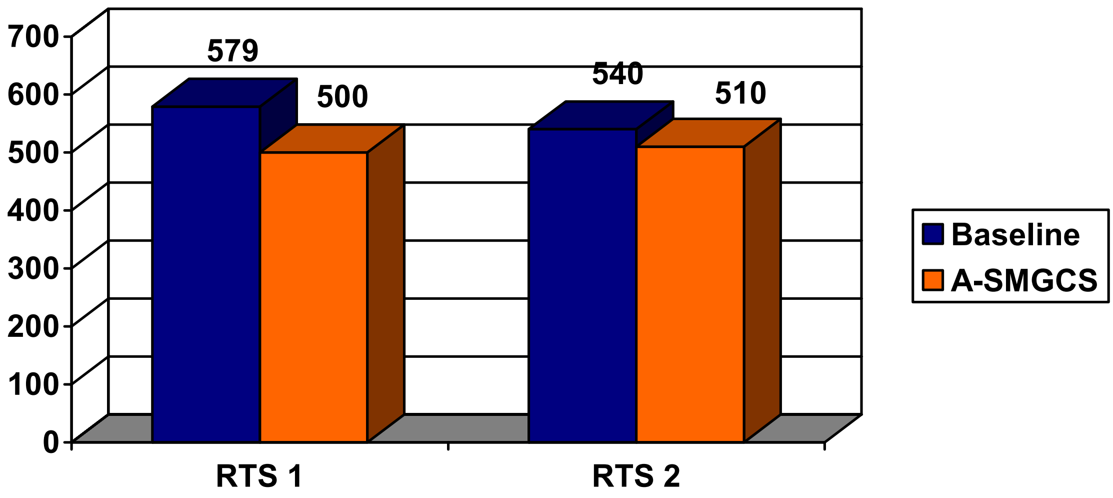


Figure 3-3: Total average Taxi Times for RTS 1 and RTS 2 [sec]

Concluding Results

The results show significant differences in the taxi times between *A-SMGCS* and the *Baseline* condition for both RTS phases: For the RTS 1 (M_{Total} = -79 seconds, $T_{(304)}$ = -7,728, $p < .05$) and for the RTS 2 (M_{Total} = -30 seconds, $T_{(178)}$ = 1,973, $p < .05$).

It has to be considered that pseudo-pilots are not affected by reduced visibility conditions and the speed of their controlled aircraft has always a constant level. Measured differences can only be interpreted as a more efficient control by the controllers using A-SMGCS.

As the patterns of Table 3-15 and Table 3-16 show: The differences are particularly high with scenario B where the visibility is good but the amount of traffic is the biggest.

Furthermore, the results of RTS 2 should be more reliable than the RTS 1 results, because lots of movements in RTS 1 are affected by evoked conflict situations that were not applied with RTS 2. However, even with RTS 1, taxi times are significantly lower with A-SMGCS compared with the baseline condition.

The H0 hypothesis OI-EFF1-H0 can be rejected and the alternative hypothesis OI-EFF1-H1 can be assumed to be valid. This means, **A-SMGCS reduces taxi times**.

3.3.2.2 Radio Communication Load

Identifier	Hypothesis
OI-EFF4-H0	There is no difference in terms of **duration of radio communications** between the Baseline and the A-SMGCS Level II.
OI-EFF4-H1	The total **duration of radio communications** is reduced as an effect of introducing the A-SMGCS Level II application and related procedures.

With both phases of the RT-Simulations, the duration of radio communication has been measured for each controller working position. The duration of a test run was one hour (3600 sec). However, if a test run lasted longer than the 3600 seconds, the recording file was cut after 3600 seconds. Therefore, all present R/T durations refer to 3600 seconds overall test time.

3.3.2.2.1 Raw Data

TPC		TEC		GEC	
Baseline	A-SMGCS	Baseline	A-SMGCS	Baseline	A-SMGCS
504	576	1980	1368	1548	1260
540	468	1872	1476	1008	1476
648	576	1656	1332	1800	1332
612	432	1764	1188	2124	1044
612	468	1908	1512	1476	1656
540	612	1800	1620	2412	1512
miss. data	miss. data	1728	1548	1620	1548
miss. data	miss. data	1620	1368	1368	1584
miss. data	miss. data	1764	1512	1800	1440
miss. data	miss. data	1764	1152	1800	1548
miss. data	miss. data	1836	1404	1224	900
miss. data	miss. data	1584	1332	1044	1260
miss. data	miss. data	1728	1692	1404	1296
miss. data	miss. data	1764	1440	1548	1476
miss. data	miss. data	1692	1260	1224	1116
576	**522**	**1764**	**1413**	**1481**	**1244**

Table 3-17: Radio Communication Load Raw Data [sec per hour] (RTS 1)

TPC		TEC		GEC	
Baseline	A-SMGCS	Baseline	A-SMGCS	Baseline	A-SMGCS
684	468	1836	1800	1944	1764
648	540	1908	1836	2268	1980
864	576	1440	1296	1620	1476
720	684	1980	1944	2088	1836
576	576	1296	1152	2304	1440
828	648	1800	1728	1368	1512
720	**582**	**1710**	**1626**	**1932**	**1668**

Table 3-18: Radio Communication Load [sec per hour] (RTS 2)

3.3.2.2.2 Results

CWP	A-SMGCS	Mean M	Standard Deviation SD	Sample Size N
TPC	ASMGCS	522,0	74,6	6
	BASE	576,0	55,7	6
TEC	ASMGCS	1413,6	151,8	15
	BASE	1764,0	106,2	15
GEC	ASMGCS	1363,2	217,2	15
	BASE	1560,0	385,9	15
Total	ASMGCS	1244,0	369,6	36
	BASE	1481,0	491,8	36

Table 3-19: R/T Load Means, SD, and Sample Size (RTS 1)

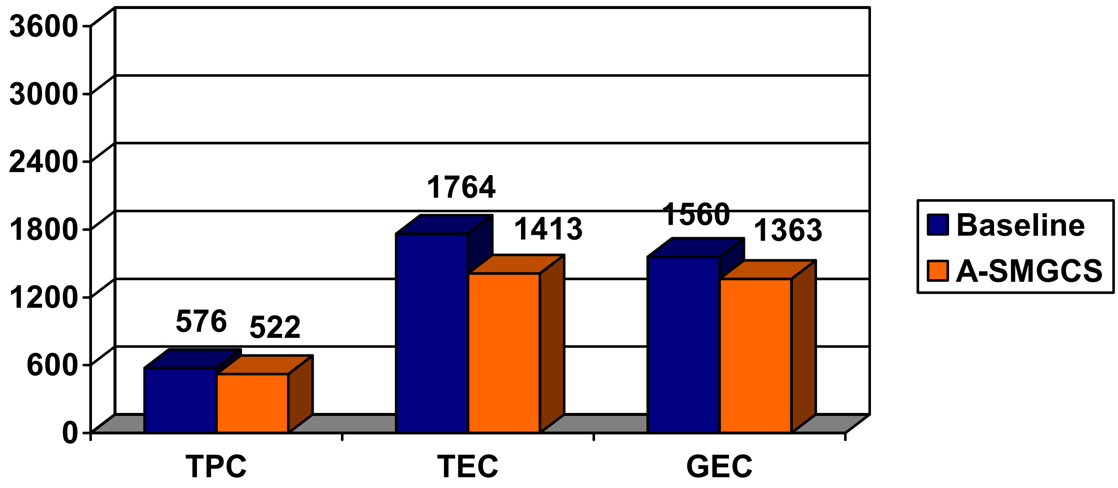


Figure 3-4: Means of R/T Load between A-SMGCS and Baseline for each CWP [sec per hour] (RTS1)

CWP	A-SMGCS	Mean M	Standard Deviation SD	Sample Size N
TPC	ASMGCS	582	76,9	6
	BASE	720	109,1	6
TEC	ASMGCS	1626	322,3	6
	BASE	1710	275,8	6
GEC	ASMGCS	1668	222,6	6
	BASE	1932	371,8	6
Total	ASMGCS	1292	560,4	18
	BASE	1454	600,3	18

Table 3-20: R/T Load Means, SD, and Sample Size (RTS2)

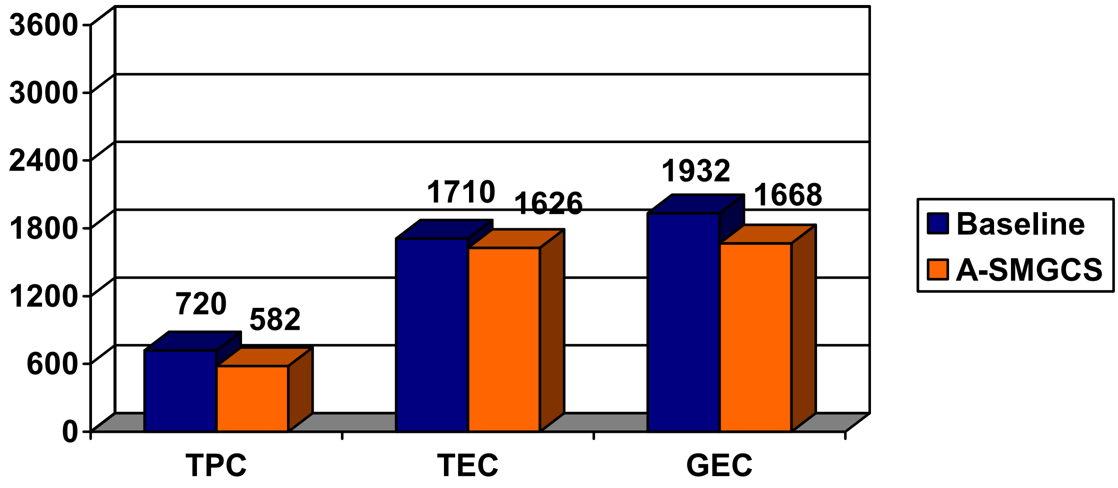


Figure 3-5: Means of R/T Load between A-SMGCS and Baseline for each CWP [sec per hour] (RTS2)

UV	QS	df	F	p-value[12]
CWP	9772362	2	98,606	0,000*
ASMGCS	602402	1	12,157	0,001*
CWP x ASMGCS	209034	2	2,109	0,129
Error	3270456	66		
Total	147924144	72		

Table 3-21: R/T Load Test for Significance (two-way ANOVA [F-Test]) (RTS 1)

UV	QS	df	F	p-value[13]
CWP	9487656,000	2	73,806	0,000*
ASMGCS	236196,000	1	3,675	0,065
CWP x ASMGCS	51192,000	2	,398	0,675
Error	1928232,000	30		
Total	79567920,000	36		

Table 3-22: R/T Load Test for Significance (two-way ANOVA [F-Test]) (RTS2)

Concluding Results

The two-way 2x3 ANOVA shows a significant result for A-SMGCS with RTS 1 with a significant mean difference of 237 seconds per hour less R/T load *($F_{(1,30)} = 12.2$, $p < .05$)*. With RTS 2, a 162 second difference between A-SMGCS and baseline was measured, which shows a positive trend to

[12] The star with a p-value shows its significance with an α = 0.05.
[13] The star with a p-value shows its significance with an α = 0.05.

assume the H1 hypothesis, but became not significant *($F_{(1,30)} = 3.6, p > .05$)*. However a p-value of 0.065 is rather close to significance and with a greater sample size the effect could also be proved.

With the interpretation of the results, it has to be regarded that with RTS 1 the controllers were very much interrupted by evoked conflict situations that did not happen with RTS 2. However, as the impact of conflicts is equal to both conditions (A-SMGCS and Baseline) a systematic effect of a variance can be excluded.

OI-EFF4-H0 can be rejected and the alternative H1 can be assumed: **A-SMGCS reduces the load of R/T communication.**

3.3.3 Human Factors

3.3.3.1 Situation Awareness

Identifier	Hypothesis
OI-HF1-H0	The ATCOs' **situational awareness** in the Baseline condition is higher or at least equal compared to the A-SMGCS Level II test condition.
OI-HF1-H1	The ATCOs' **situational awareness** is improved as an effect of introducing the A-SMGCS Level II application and the related procedures.

3.3.3.1.1 SASHA Questionnaire Results

After each test run the controllers' situation awareness was measured with the SASHA Questionnaire. This questionnaire was developed within the project "Solutions for Human-Automation Partnerships in European ATM" (SHAPE) conducted by EUROCONTROL (2003)[14]. The questionnaire uses a five-point scale and contains 12 questions, of which eight questions address generic subjective aspects of SA referring to the work of an ATCO, three questions addressing aspects of specific tools, and one question addressing SA globally. Each ATCO completes the questionnaire at the end of a test run. These ratings have been merged to two scores per controller, one for the EMMA A-SMGCS and one for the baseline condition.

Following raw data have been measured:

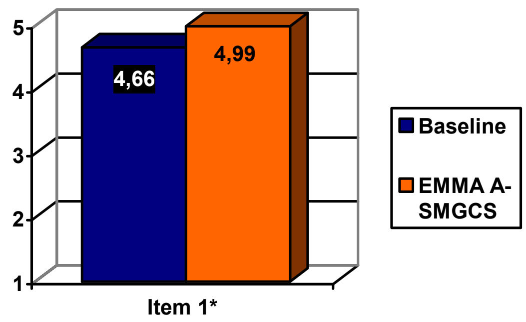
[14] http://www.eurocontrol.int/humanfactors/gallery/content/public/docs/DELIVERABLES/HF35-HRS-HSP-005-REP-01withsig.pdf

item1		item2		item3		item4		item5		item6		item7		item8		item9		item10		item11		item12	
em1	**ba1**	**em2**	**ba2**	**em3**	**ba3**	**em4**	**ba4**	**em5**	**ba5**	**em6**	**ba6**	**em7**	**ba7**	**em8**	**ba8**	**em9**	**ba9**	**em10**	**ba10**	**em11**	**ba11**	**em12**	**ba12**
4,84	4,84	4,67	4,67	4,67	4,67	1,17	1,50	1,50	1,00	1,00	1,50	4,50	3,83	2,17	1,67	4,33	4,00	3,20	n.a.	3,80	n.a.	4,67	4,67
5,00	5,00	4,83	5,00	4,83	5,00	1,17	1,33	1,00	1,50	1,67	1,67	4,83	5,00	2,33	2,50	4,67	4,83	4,33	n.a.	4,33	n.a.	4,67	5,00
4,84	4,66	4,50	4,83	4,50	4,83	1,20	1,00	1,25	1,50	1,17	2,00	4,17	4,50	1,67	1,83	4,67	4,00	3,67	n.a.	4,17	n.a.	4,50	4,50
5,00	4,50	4,83	4,83	4,83	4,83	1,00	1,00	1,00	1,00	1,00	1,33	4,50	3,67	2,33	2,50	4,67	4,17	3,25	n.a.	2,33	n.a.	4,50	4,00
4,50	4,66	4,83	4,83	4,83	4,83	1,00	1,00	1,00	1,33	1,33	1,00	4,67	4,67	3,67	1,50	5,00	4,33	3,20	n.a.	3,25	n.a.	4,75	4,60
5,00	4,00	5,00	4,33	5,00	4,33	1,33	1,67	1,33	1,33	1,33	2,67	4,33	2,67	2,67	2,67	4,67	3,00	4,33	n.a.	3,67	n.a.	5,00	4,00
5,00	4,33	5,00	4,33	5,00	4,33	1,33	1,33	1,00	2,00	1,67	2,00	3,67	3,67	3,33	2,33	4,33	3,00	3,33	n.a.	3,00	n.a.	4,67	3,33
5,00	5,00	5,00	4,33	5,00	4,00	2,00	1,50	1,33	1,00	2,67	2,00	4,00	3,00	2,33	2,00	3,67	3,00	3,33	n.a.	3,00	n.a.	3,67	3,50
5,00	5,00	5,00	5,00	5,00	5,00	1,00	2,00	1,50	1,33	1,00	2,00	4,00	4,33	2,33	2,67	4,67	5,00	3,00	n.a.	3,00	n.a.	4,67	4,00
5,00	4,33	5,00	4,67	5,00	4,67	1,33	2,67	1,00	1,33	1,00	2,00	4,67	2,67	3,33	3,00	4,33	2,67	4,00	n.a.	4,00	n.a.	4,67	3,33
4,67	5,00	4,67	5,00	4,67	5,00	1,00	1,67	1,33	1,00	1,33	1,33	4,67	4,00	2,33	3,33	5,00	3,00	5,00	n.a.	4,00	n.a.	4,67	4,00

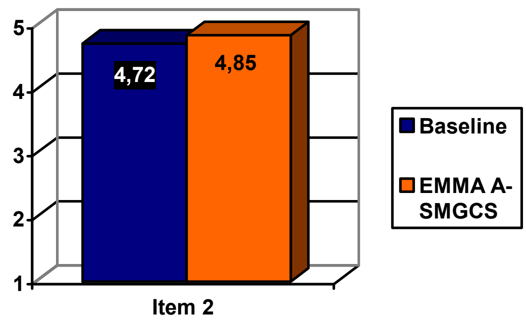
em EMMA A-SMGCS test condition
ba Baseline test condition

Table 3-23: Raw Data SASHA Questionnaire

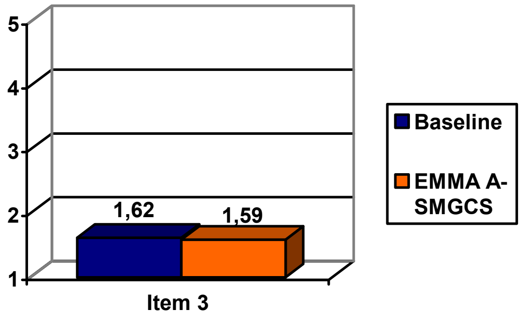
The following bar charts show the mean values for each of the 12 SASHA questionnaire items. The star with a p-value shows the significance of an item, which means the controller commonly saw differences between the A-SMGCS and baseline conditions with respect to the assumption of the alternative hypothesis (H1).



1. Did you have the feeling that you were ahead of the traffic, able to predict the evolution of the traffic?
p = 0.04*

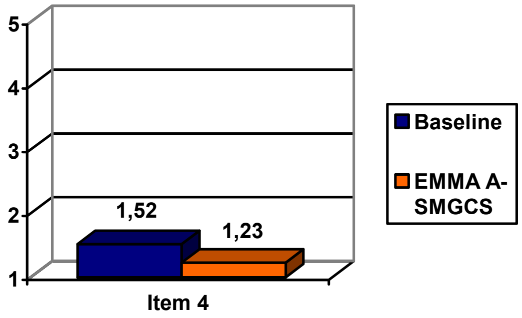


2. Did you have the feeling that you were able to plan and organise your work as you wanted?
p = 0.133



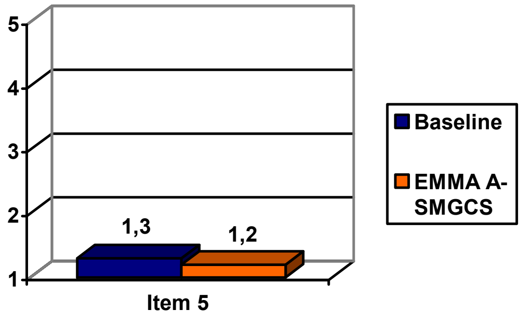
3. Have you been surprised by an aircraft (or vehicle) call that you were not expecting?

p = 0.44



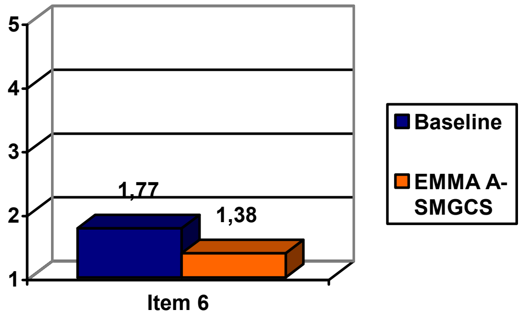
4. Did you have the feeling of starting to focus too much on a single problem and/or traffic area under your control?

p = 0.05



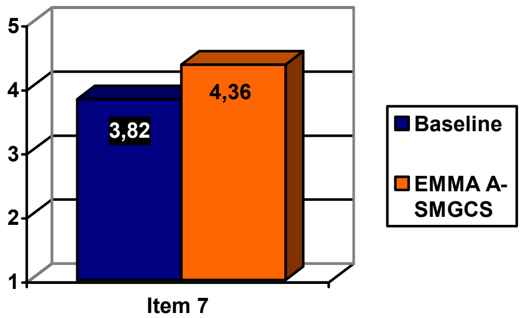
5. Did you forget to transfer any aircraft?

p = 0.24



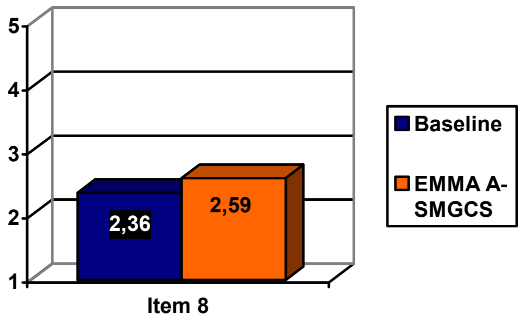
6. Did you have any difficulty finding an item of information?

p = 0.03*



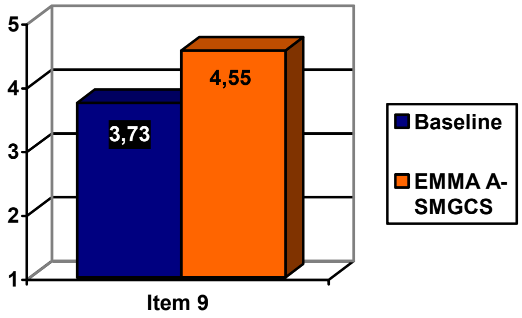
7. Do you think the *A-SMGCS / SMR Display* provided you with useful information?

p = 0.02*



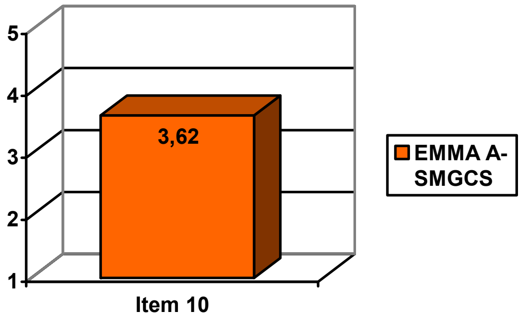
8. Were you paying too much attention to the *A-SMGCS / SMR Display*?

p = 0.19



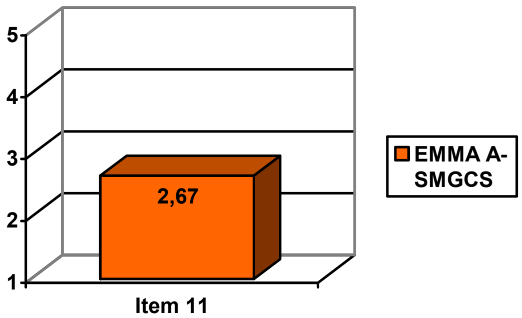
9. Did the *A-SMGCS / SMR Display* help you to have a better understanding of the situation?

p = 0.03*



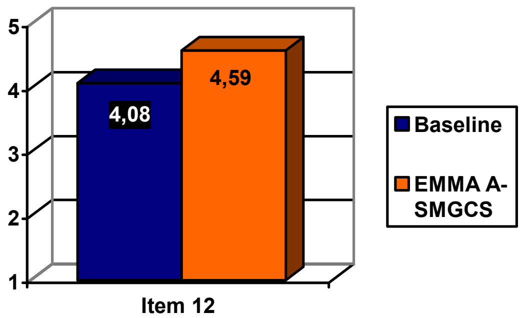
10. Do you think the *RWY incursion alert function* provided you with useful information? (only with A-SMGCS test run)

p = 0.00*



11. Did the *RWY incursion alert function* help you to have a better understanding of the situation? (only with A-SMGCS test run)

Mean is lower than 3



12. How would you rate your overall Situation Awareness during this exercise?

p = 0.01*

Concluding Results

Six of the 12 questionnaire items have been significantly answered in the expected direction, five showed the right trend but without significance, and item 11 was answered in the non-expected direction. However, the main situation awareness item 12 has been answered significantly, supporting the hypothesis OI-HF1-H1, which expects a higher SA with A-SMGCS use.

With this result, the OI-HF1-H0 can be rejected and the H1 can be assumed as valid alternative that means **A-SMGCS increases the Controller's Situation Awareness**.

3.3.3.1.2 SASHA on-line Questionnaire Results

This technique is based on the Situation Present Assessment Method (SPAM). Five ATCOs of the RTS 1 were asked three questions by a subject matter expert (SME) via their intercom within each test run. This was done while the simulation was still running, i.e. the simulation was not frozen like in the classical SAGAT query technique. The following questions were asked:

1. Where is flight *x*?
2. Is flight *y* under your control?
3. Which flight has to be transferred next?

The SA of the ATCOs is usually that high that they do not give wrong answers. The following table shows the small cases where they gave wrong answers:

	Scenario A						Scenario B						Scenario C					
	A-SMGCS			Baseline			A-SMGCS			Baseline			A-SMGCS			Baseline		
	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC	TPC	TEC	GEC
C1							0	0	0	0	0	0	0	0	0	0	0	1
C2							0	0	1	0	0	0	0	0	0	0	0	0
C3							0	0	0	0	1	0	0	0	0	0	0	0
C4		0	0		1	0		0	0		0	2		0	0		0	0
C5		0	1		0	0		0	0		0	0		0	0		0	0
Total		**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	1
	1			**1**			**1**			**3**			**0**			**1**		

Table 3-24: Raw Data of Wrong Answers with the SAHA on-line Query (RTS 1 only)

Concluding Results

In total 180 (3 times per test run and CWP) questions have been asked to the controllers, but only 7 wrong answers have been given. Among these 7 wrong answers, 5 have been given when A-SMGCS was not used. This result is far from statistically significance but it further supports the hypothesis OI-HF1-H1, which expects a higher SA with A-SMGCS use.

3.3.3.2 Workload

Identifier	Hypothesis
OI-HF3-H0	When workload is on a non-convenient level, the controllers' **workload** with the A-SMGCS Level II test condition is not lower compared to Baseline test condition.
OI-HF3-H1	When workload is on a non-convenient level in the baseline condition, the **workload** with use of an A-SMGCS would be reduced with the same scenario.

With every test run every controller was asked to give his perceived workload rating every 10 minutes. The controller could choose one of five I.S.A. workload categories:

1 = underutilised
2 = relaxed
3 = comfortable
4 = high
5 = excessive

For the analysis, the I.S.A. mid-run workload scores were summed up over each Controller for each test run and respective mean scores were calculated (cf. Table 3-25).

	A		B		C	
	A-SMGCS	Baseline	A-SMGCS	Baseline	A-SMGCS	Baseline
C1	1,8	2,8	2,6	2,9	2,1	2,2
C2	2,4	2,8	2,1	2,1	2,4	1,9
C3	2,0	2,6	2,2	2,0	2,1	2,1
C4	2,9	2,9	3,1	3,4	2,6	2,3
C5	3,2	2,7	2,7	3,0	2,5	2,7
C6	2,4	2,2	2,0	2,2	2,2	2,2
C7	2,6	2,0	2,0	2,0	2,0	1,6
C8	3,2	2,0	2,0	2,4	2,2	2,0
C9	2,0	2,0	2,0	2,0	2,0	2,0
C10	1,8	2,2	2,0	2,0	2,0	2,0
C11	2,2	2,0	1,8	2,0	2,0	2,2
Total	**2,41**	**2,38**	**2,23**	**2,36**	**2,19**	**2,11**

Table 3-25: Mean Values of I.S.A. Workload

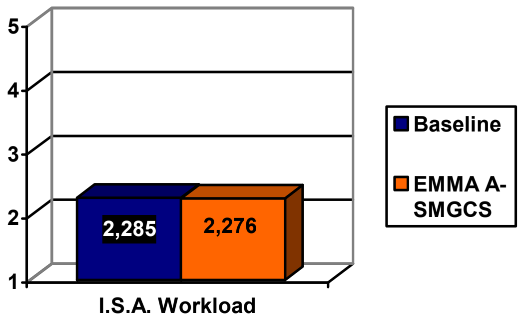


Figure 3-6: Total Means for I.S.A.[15] Workload between A-SMGCS and Baseline Test Conditions

Factors	df	F-value	p-value
A-SMGCS	1	0,019	0,89
error	10		
Traffic scenario	2	4,540	0,02*
error	20		
asmgcs * scenario	2	0,869	0,44
error	20		

Table 3-26: ANOVA with Repeated Measurements for I.S.A. Workload

The means from Table 3-25 were analysed in separate 2 x 3 (A-SMGCS x Scenario) analyses of variance (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 1-5. A significant main effect for the traffic scenario was found ($F_{(2,20)}$ = 4,540; p = 0.02), whereas traffic scenario C reaches the smallest workload

[15] "Instantaneous Self Assessment" workload scale is a mid-run assessment tool with five dimensions ranging from "underutilised" through "excessive".

mean (M_A = 2,40; M_B = 2,30; and M_C = 2,15), where the visibility is the lowest but also the traffic amount is only the half of scenario A or B.

Concluding Results

Most of the time the controllers felt relaxed and comfortable in the simulation runs, independent of the test condition *A-SMGCS* or *Baseline*. Traffic scenarios were not demanding enough to stress the controllers. Therefore, A-SMGCS had no chance to show a workload improvement compared to a *high* or even *excessive* workload in the baseline condition.

Since a "non-convenient workload level" as stated by OI-HF3-H0 could not be reached, A-SMGCS could not show its benefits in terms of workload reduction. Therefore, OI-HF3-H0 cannot be rejected with the used experimental design.

3.4 Departure Manager (DMAN) Demonstration Results

During the second EMMA RTS phase in the Tower Simulator in Braunschweig, the DMAN was demonstrated to the two controller teams from the Prague Tower, who participated in the RTS trials. For each team, consisting of three controllers, one day had been allocated, with the possibility to run different simulation scenarios several times and with different controllers at the working positions.

The goals of the simulation exercises were mainly to show the technical feasibility of departure planning, to make the controllers familiar with using a planning tool and to demonstrate what information can be provided to the controller concerning the anticipated ground traffic operations.

At the present state of development, it was not intended to perform tests concerning the operational usability of the DMAN or possible operational improvements, since there was a technical HMI to be used, and the controllers had no training in operating the DMAN.

3.4.1 Course of the Demonstration

For both demonstration days, the following schedule had been arranged:

- Briefing
- Familiarisation with the DMAN in the small technical scenario EMMA_T1, optionally to be repeated
- Demonstration of the DMAN in the complex operational scenario EMMA_A1
- Debriefing
- Break
- Second demonstration of the DMAN in the complex operational scenario EMMA_A1
- Final debriefing

For all simulation runs, the following human roles at the working positions had been scheduled:

- TEC: 1 Prague controller and 1 DLR assistant for explanations and support in operating the DMAN HMI.
- CEC + GND: 1 Prague controller and 1 DLR assistant for explanations and support in operating the DMAN HMI.
- E2000: 1 Prague controller as an observer

The aircraft in the simulation were again individually controlled by DLR pseudo-pilots, using R/T voice communication between pilots and controllers.

The simulation exercises were managed by a DLR supervisor and a DMAN specialist.

Both days the session started with a briefing, where a presentation on the DMAN was given to the controllers, and the intentions and the course of the simulation exercises were explained. In the subsequent discussion, the controllers expressed concerns with respect to additional workload possibly caused be the use of a planning tool.

The simulation exercises started with the small technical scenario EMMA_T1 for familiarization. First, the HMIs were explained in detail by the assistants. During the simulation run, the controllers managed the traffic and observed the DMAN, and the assistants performed the clearance and hand-over entries at the DMAN, and gave explanations. Very soon, some of the controllers started to make the entries by themselves, and also to check, how diverse flight plan items could be changed. It had to be explained that arbitrary changing vital flight plan data would disturb the planning process, which in one case led to repeating the scenario. Nevertheless, it was useful to show the diverse capabilities of the DMAN HMIs, and how diverse flight plan items can be adjusted in accordance to the controller's intentions.

The complex operational scenario EMMA_A1 was performed twice and the controllers changed the working positions at each run. In the beginning, the assistants had to support the operation of the DMAN, but the more the controllers got used to it, the more they operated the DMAN by themselves. The controllers observed closely the information provided by the DMAN displays, and how the planning results performed. With progress of the simulation exercise, they handled more sophisticated procedures like changes of the assigned runway and intersection take-offs.

3.4.2 Results

There were two sources during the DMAN trials to gain the qualitative/subjective results:

- Observations made during the simulation runs.
- Comments made by the controllers during the briefings, simulation runs and debriefings.

For each category a short summary shall be given.

Observations:

- During all simulation runs the DMAN performed well. The planning results were timely and in accordance with the respective traffic situation, even when flight plan data had been manually changed by the controllers due to changed procedures.
- The simulation scenarios were well-suited for the demonstration purposes. The small technical scenario with its low traffic density gives enough time for the assistants to explain how the DMAN HMIs have to be operated, and allows the controllers to familiarise themselves with the information provided at the displays and the required entries, without being under pressure by managing a complex traffic scenario. The complex operational scenario has been evaluated and approved throughout the first EMMA RTS phase, and provides a traffic flow and traffic operations to which the controllers are used from their daily work in Prague.
- The simulation runs went smoothly, with the traffic professionally managed by the controllers, and by the pseudo-pilots.
- The controllers soon became acquainted with the DMAN displays, and correlated the actual and upcoming traffic situation with the information provided by the flight strips generally well.
- Though the controllers had to operate the DMAN via technical HMIs, which are not meant for operational use, they were relatively soon able to perform clearance and handover entries by themselves, without being distracted too much from managing the traffic.
- The controllers were generally interested in the information provided by a planning tool, and tried to check out the capabilities of the DMAN. They handled intersection take-offs with change of runway entry point and also changes of the assigned runway.

Comments by the Controllers:

Most of the comments given by the controllers were related to the HMI subject and the resulting workload, though it was made clear beforehand, that the presented technical HMI is not intended for operational use in the tower.

The respective concerns of the controllers will be taken into account in EMMA2, when as planned an integrated A-SMGCS HMI comprising DMAN HMI functionality will be developed.

- The present HMIs require too much head-down time.
- Traffic control, coordination with other authorities at the airport and additionally operating the DMAN will overload the controller.
- An A-SMGCS display together with a separate DMAN display is no suitable solution, since the controller has to look out of the tower windows and also to check two displays and operate the system. This leads to too much head-down time, increases the workload and distracts the controller from his primary task.
- The solution should be an integrated A-SMGCS display, where the traffic information together with the planning information is shown.
- The information given by the planning function should be reduced to the amount really necessary for the controller.
- Entries at the HMI require too many mouse clicks at different locations in the display. For instance, the confirm button could be replaced by a double-click.
- The number of required HMI entries should be reduced by more automation.
- The HMI column, which notes the next clearance, is misleading, since controllers are used to note given clearances.
- Entries at the DMAN, which change flight plan data, must feed back to other systems; e.g. information also shown in the labels on the traffic situation display must change in accordance.
- Several times it was stated, that apart from the HMI issues the DMAN works well and stable, ant that the planning function provides reasonable results.

Altogether it was acknowledged, that with an integrated, easy to handle A-SMGCS HMI the DMAN would be a valuable tool.

4 Operational Field Trials Results

4.1 Introduction

Operational Field trials in the operational Tower at Prague Ruzyne Airport were conducted on the 3rd of November 2005, 16th through 18th and 23rd through 25th of January 2006.

The operational field trial exercises used the A-SMGCS test-bed components at Prague-Ruzyne airport, established under SP3 of the EMMA Project, and the commercial A-SMGCS that was already used fully operationally from mid of 2005. The Validation Platform is described in the EMMA Prague Test Plan [13].

4.2 Operational Feasibility (Field Trials)

The operational feasibility tests aim at assessing the user's acceptance of the EMMA ORD [10] operational procedures and requirements. It was expected that the operational feasibility of the system would be confirmed, for each set of visibility conditions, using defined procedures derived from EMMA Operational Requirements Document (ORD). The following general hypothesis has been used to decide upon the test results:

High-level Objective 1	EMMA A-SMGCS shows the operational feasibility of the operational procedures and requirements expressed in the initial EMMA ORD [10] for each set of conditions.

To prove the operational feasibility of the installed A-SMGCS three main exercises were conducted:

1. Debriefing Questionnaires and Interviews
2. Long Term Alert Performance Assessment
3. Flight Tests with test aircraft and test vehicles

The following sections give details and results to each exercise.

4.2.1 Debriefing Questionnaire (operational feasibility)

A total of 15 ANS-CR controllers filled out the debriefing questionnaire during the EMMA operational field trials. All 15 ANS_CR had worked with the A-SMGCS for 7 months at the time of the investigation. The table below shows the distribution of age, gender, and ATC experiences:

	Category	N
Age	20-29	2
	30-39	8
	40-49	3
	>50	2
Gender	male	12
	female	3
ATCO Experience (years)	<5	3
	6-10	3
	11-15	7
	16-20	0
	21-25	1
	> 26	1

Table 4-1: Social-Demographic Data of the Sample Size

A 144 item debriefing questionnaire were given to 15 ANS_CR controllers after their regular shift. The items that refer to the“operational feasibility” questions/statements loaded to five areas:

- General usability,
- Surveillance service,
- Control service,
- HMI design, and
- New or potential procedures.

The following general hypothesis was set up to describe the expectation with the controllers' answers:

Identifier	Hypothesis
OF-H0	The controllers' opinion does not agree to the "operational feasibility" aspects of a specific item.
OF-H1	The controllers' opinion agrees to the "operational feasibility" aspects of a specific item.

Ratings to a statement could be given from 1 (strongly disagree) up to 6 (strongly agree). The following table shows the raw data of the complete Debriefing Questionnaire (including *operational improvement* items). The VA-Id. number identifies the items, C1 through C15 identifies the index of the 15 ANS_CR controllers, a bold number shows that a comment has been given, and a star (*) indicates that a comment was given but without a rating.

VA-Id.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
1	5	5	5	6	5	5	5	6	5	5	5	4	5	5	5
2	5	5	5	6	5	5	4	6	5	5	5	3	3	5	4
3	5	5	5	6	6	5	6	6	5	6	5	5	6	5	5
4	1	4	2	2	3	4	4	4	2	2	2	3	3	5	3
5	2	5	1	2	3	3	5	3	3	5	5	3	*	5	3
6	1	3	1	2	2	1	1	1	2	1	1	2	3	5	2
7	5	4	2	5	5	2	2	2	4	3	2	3	4	4	4
8	4	4	2	4	4	5	5	5	4	6	5	4	4	5	4
9	5	5	6	5	1	6	6	6	6	6	5	5	6	5	5
10	5	5	6	4	5	5	6	5	5	6	5	5	6	5	5
11	5	5	6	5	6	**2**	6	5	6	6	**4**	5	4	5	5
12	5	5	6	6	5	5	6	5	6	6	5	6	5	5	5
13	5	5	4	6	5	5	5	5	6	6	6	5	5	5	6
14	2	2	1	1	1	2	2	2	2	1	2	1	6	4	2
15	4	3	5	4	5	5	5	*	5	5	4	5	6	5	**2**
16	5	5	6	5	6	5	5	5	5	6	5	5	6	5	5
17	5	4	6	5	6	**4**	5	5	2	6	3	5	2	5	5
18	4	3	2	5	3	**4**	4	5	3	2		3		4	*
19	4	4	5	5	5	5	4	4	4	5		3	4	5	*
20	5	5	5	2	2	2	2	2	4	1	3	3	2	3	1
21	4	5	2	4	2	4	6	5	3	4	4	4	2	5	4
22	3	4	4	5	4	4	6	5	5	6	5	5	5	4	6
23	5	4	5	5	6	6	6	5	6	6	5	5	6	5	6
24	3	4	4	4	5	4	6	5	5	5	5	5	6	4	6
25	5	5	6	6	5	5	6	5	5	6	5	5	5	5	2
26	5	5	6	5	5	5	6	5	6	6	5	5	5	6	3
27	5	5	5	5	5	5	4	5	5	6	5	5	5	5	4
28	5	5	6	6	5	5	5	5	6	6	5	6	5	6	5
29	5	5	6	6	4	4	5	5	6	6	4	5	6	6	5

VA-Id.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
30	2	3	2	2	2	3	*	1	2	4	2	4	4	6	2
31	2	3	2	2	2	3	*	1	3	4	2	4	4	5	2
32	2	3	2	2	2	3	*	1	4	5	2	4	5	5	2
33	5	4	5	4	4	**5**	4	5	4	4	4	4	2	5	4
34	5	4	5	4	3	5	4	4	3	5	4	3	4	5	3
35	2	4	5	5	5	**4**	3	2	2	5	5	4	2	5	**4**
36	5	5	5	5	4	5	5	5	5	6	**3**	5	6	5	5
37	5	5	5	5	5	5	5	5	5	6	3	5	5	5	4
38	5	3	6	5	4	4	4	5	6	6	1	**6**	5	5	5
39	3	3	4	5	2	4	5	5	1	5	4	3	4	4	5
40	3	4	5	5	**4**	5	5	3	5	5	2	4	6	4	2
41	3	4	5	5	3	5	5	5	2	5	4	5	5	6	5
42	3	4	6		2	*	5	*	5	6		5		6	4
43	5	5	6	4	4	5	5	5	3	6	5	5	5	5	5
44	3	5	5	6	2	5	6	5	4	5	5	1	5	5	5
45	4	5	5	6	2	5	5	5	3	5	5	5	6	5	5
46	5	5	6	6	5	5	5	5	5	6	5	5	6	5	5
47	4	5	5	5	1	5	5	5	3	6	5	5	6	6	5
48	5	5	5	5	5	5	5	5	4	6	5	5	6	5	5
49	1	5	6	5	1	5	1	3	5	5	4	**5**	6	4	4
50	5	5	6	5	1	5	5	4	5	6	5	6	6	6	5
51	5	4	6	5	3	5	5	5	4	4	4	4		6	4
52	4	4	6	5	2	5	4	5	4	5	4	4	6	6	4
53	5	5	6	5	5	5	4	5	5	6	5	4	6	5	5
54	3	5	3	5	2	5	5	5	4	6	5	5	6	6	2
55	5	5	6	6	6	5	5	5	4	6	5	5	6	6	5
56	2	5	6	5	1	4	**1**	5	4	5	3	5	5	5	**4**
57	2	5	6	5	2	4	**1**	5	5	6	3	4	5	5	**4**
58	5	5	6	5	4	5	5	5	3	6	5	3	6	5	5
59	5	5	6	5	5	5	5	5	5	6	4	5	6	6	5
60	2	3	**4**		1	**2**	**1**	2	2	2		3		3	2
61	6	5	5	*	*	5	5	5	4	5	2	5	6	6	5
62	6	5	5		*	5	5	5	4	5	3	5	6	6	5
63	**5**	4	4		6	5	5	5	4	6	5	5	4	5	5
63a											5	5	5	6	5
64		3	4		*	*	*	*	3	2		*	2	5	2
65		2	4		*		*	*	3	6		*	2	3	**4**
66		4	4		*		*	*	4	2		*	6	5	4
67		4	4		*		*	*	4	5	**2**	*	6	6	4
68		3	4		*		*	2	2	4		*	3	3	4
69		4	5		*		*	2	3	2		*	1	4	2
70	5	5	3		**5**	4	5	5	5	4	5	5	5	5	5
71	2	3	4		4	**5**	2	2	2	5	2	2	2	2	2
72	3	5	6	5	6	5	6	5	5	6	4	5	6	5	5
73	2	2	2	2	1	2	1	2	2	1	2	1	2	1	2
74	5	4	5	4	1	2	5	4	2	6	3	4	6	4	3
75	5	5	5	5	5	4	5	5	4	6	5	5	6	6	5
76	1	2	2	2	1	1	1	2	1	2	2	1	1	1	2
77	5	4	5	4	2	5	5	5	4	5	5	4	6	5	3
78	5	4	5	5	**6**	5	6	5	5	6	5	6	6	5	5
79	5	5	5	5	5	5	6	5	5	6	5	5	6	6	3
80	5	4	5	5	6	5	5	5	4	6	6	5	5	5	4
81	4	3	4	5	2	4	5	3	4	4	4	4	3	5	2
82	5	3	5	5	5	5	5	5	5	5	4	5	5	6	5
83	2	3	4	2	5	3	5	*	3	2	*	4	5	5	4

VA-Id.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
84	5	4	5	4	6	4	5	5	4	5	5	5	3	5	5
85	5	3	**3**	4	4	3	2	2	3	2	3	1	2	5	2
86	5	4	5	5	3	5	5	5	5	6	6	5	6	5	6
87	2	2	2	1	2	2	2	2	3	2	4	1	4	5	2
88	5	5	5	5	6	5	5	5	5	6	4	5	3	5	5
89	2	2	2	5	2	2	2	2	2	2	**2**	2	4	4	2
90	2	2	2	1	1	2	1	2	2	2	2	5	1	2	2
91	5	5	5	4	6	5	5	5	4	5	5	5	4	4	5
92	2	3	4	4	4	3	2	2	2	2	2	3	4	3	3
93	5	5	5	5	6	5	5	5	5	5	4	5	5	5	5
94	5	5	4	4	4	5	4	5	5	6	5	5	4	5	4
95	5	4	6	4	4	5	6	5	6	6	6	5	6	2	5
96	5	4	5	4	5	5	5	5	4	5	4	5	5	5	5
97	5	4	5	3	1	5	5	5	5	3	5	5	5	5	5
98	5	4	5	4	6	5	5	5	6	5	5	5	6	6	5
99	5	4	5	4	6	5	5	5	5	5	5	5	6	5	5
100	5	4	5	4	6	5	5	5	4	5	5	5	6	6	5
101	5	2	5	3	6	5	5	5	5	4	4	5	3	5	5
102	5	5	5	5	6	5	5	5	5	4	5	6	6	5	5
103	5	4	4	4	**3**	5	**3**	5	5	4	5	6	6	6	5
104	2	3	2	2	**2**	2	2	2	4	2	3	2	4	3	2
105	2	2	2	**5**	1	2	**5**	2	2	2	**5**	**4**	2	2	2
106	5	4	5	5	6	5	5	5	4	5	5	5	5	4	5
107	5	4	5	4	6	4	5	5	3	5	**2**	5	1	5	**2**
108	5	4	5	5	6	4	5	5	3	5	4	5		5	**4**
109	3	4	4	4	4	2	2	4	6	3	2	3	4	3	**5**
110	5	5	5	5	5	5	5	5	4	5	5	5	6	5	5
111	4	5	3	5	**5**	5	5	5	4	4	5	5	2	6	4
112	5	5	5	5	**2**	5	5	5	6	6	4	5	6	5	4
113	5	5	5	6	**1**	5	5	5	4	6	5	5	6	6	5
114	5	5	5	6	**1**	*	4	5	4	6	5	5	5	6	5
115	5	5	5	6	**1**	*	*	5	4	6	5	5	5	6	5
116	5	4	5	4	**1**	4	4	5	5	6	5	4	5	5	5
117	5	4	5	5	5	5	5	5	5	6	5	4	5	6	**3**
118	2	2	2	2	2	2	2	2	2	1	5	5	5		4
119	2	2	2	4	2	3	2	2	4	4		*	**4**	5	**4**
120	5	2	3	2	1	2	1	2	2	1					
121	5	2	3	4		3	5	5	4	5					
121a											2	2	5	5	3
122	5	2	2	5	5	3	5	5	5	5	4	5	5	5	4
123	6	2	2	5	**2**	5	5	5	5	6	4	5	6	5	3
124	5	2	2	5	5	5	5	5	5	6	4	5	5	5	4
125	5	5	5	5	5	5	5	5	5	6	6	5	5	6	5
126	5	4	5	5	4	5	5	5	5	6	5	5	5	5	4
127	5	2	3	5	5	5	4	5	4	6	4	5	5	4	4
128	2	4	3	4	2	4	2	5	2	5	3		5	5	2
129	3	2	3	3	1	4	3	2	3	5					
130	3	2	5	3	1	3	4	2	3	2	2	2	1	3	**4**
131											5	5	6	5	4
131	5	5	5	5	6	5	5	5	5	5	5	5	6	6	5
132	2	2	2	2	2	2	2	2	2	3	2	2	2	4	3
133	3	4	3	4	3	4	4	2	3	4	2	3	2	3	2
134	5	5	5	5	6	5	5	5	4	5	5	5	5	5	5
135	5	5	5	5	*	5	5	5	5	5	5	6	6	6	2
136	5	5	5	5	4	4	4	5	4	6	4	5	5	6	5

VA-Id.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
137	5	4	5		5	5	5	*	4	5	4	5		5	3
138	2	2	2	5	2	2	2	2	3	2	2	2		4	2
139	5	4	5	5	4	5	4	5	4	6	4	5	5	4	5
140	5	5	5	5	6	5	5	5	5	6	3	5	3	5	5
141	5	5	5	5	6	5	5	5	5	6	3	5	3	5	5
142	2	2	2	2	2	2	2	2	2	2	3	2	5	5	2
143	5	4	4	4	5	4	5	5	5	5	3	5	5	5	5
144	5	4	**3**	4	5	4	*	5	5	5	1	5	5	5	5

Table 4-2: Debriefing Questionnaire Raw Data (Field Trials)

A one-sample t-test has been applied to prove the data for their statistical significance for all 144items.

- One-Sample T-Test
- Expected mean value = 3,5
- Answers from 1 (disagreement) through 6 (agreement)
- N = 15
- $\alpha = 0.05$
- p-value is single-sided because of the use of a directed hypothesis

Results referring the "operational feasibility" items are reported with sections 4.2.1.1 "General", 4.2.1.2 "Surveillance", 4.2.1.3 "Control", 4.2.1.4 "HMI", and 4.2.1.5 "Procedures". Results to the "operational improvement" items can be found in section 4.3.1.

A star (*) with the p-value means that a item has been answered significantly because the p-value is equal or less than the critical error probability α, which is 0.05. Additionally, such items are coloured green.

When the controllers significantly express their acceptance to a single service or procedure item, it can be assumed that the operational feasibility is proven for this area of interest.

Items written in italics could not be answered meaningfully because the controllers had limited or no operational experience with the topic (e.g. except in the case of lit stop bar crossing, no system alerts have been used operationally by the ATCOs). When controller comments were given to an item, they are reported directly below the statement.

In addition to that, the sources of each item are reported. Sources are requirements or procedures reported in the ORD [10] and TRD [17].

4.2.1.1 General

VA-Id.	Questionnaire Item	N	Mean	SD	p
78	I used the A-SMGCS frequently.	15	5,3	0,6	0,00*
	Comment by ATCO E: During LVP operated				
80	The A-SMGCS is highly relevant for my work.	15	5,0	0,7	0,00*
82	I feel very confident using the A-SMGCS.	15	4,9	0,6	0,00*
85	Under visibility 1 / good visibility conditions A-SMGCS provides no additional information.	15	2,9	1,2	0,08
	Comment by ATCO C: … but I still use it.				

86	It is helpful to use A-SMGCS when visual reference is impaired	15	5,1	0,8	0,00*
87	I find the A-SMGCS unnecessarily complex.	15	2,4	1,1	0,00*
95	The A-SMGCS display gives me information which I missed before.	15	5,0	1,1	0,00*
117	I experienced the level of safety by using the A-SMGCS as very high.	15	4,9	0,7	0,00*
	Comment by ATCO O: Slightly disagree. I am especially referring to the indication of blocked RWY. The mouse is not always at hand's reach and, especially in busy hours, it is difficult to operate this function. It's happened often that we executed DEP/ARR without switching off the indication.				
135	The A-SMGCS display makes it easier to detect potentially problematic situations.	14	5,0	1,0	0,00*
140	It is easy to learn to work with A-SMGCS.	15	4,9	0,8	0,00*
141	I would imagine that most operational personnel would learn to use A-SMGCS very quickly.	15	4,9	0,8	0,00*
142	I needed to learn a lot of things before I could get going with the A-SMGCS.	15	2,5	1,1	0,00*
143	There was enough training on the display, its rules, and its mechanisms.	15	4,6	0,6	0,00*
144	There was enough training on how to control traffic with the use of the A-SMGCS.	14	4,4	1,2	0,02*
	Comment by ATCO C: It was really easy for me; I needn't any special training on. Comment by ATCO G: There was none, do we need any?				

Table 4-3: Debriefing Questionnaire – Means, SD, and P-Value for "General" operational feasibility items

4.2.1.2 Surveillance

VA-Id.	Questionnaire Item	ORD / HMI	TRD	N	Mean	SD	p
1	When visual reference is not possible, the displayed position of the aircraft in the runway sensitive area is accurate enough to exercise control in a safe and efficient way.	OP_Perf-05 OP_Serv-11	Tech_Surv_26	15	5,1	0,5	0,00*
2	When visual reference is not possible, the displayed position of vehicles in the runway sensitive area is accurate enough to exercise control in a safe and efficient way.	OP_Perf-05 OP_Serv-11	Tech_Surv_26	15	4,7	0,9	0,00*
3	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.	OP_Perf-05 OP_Serv-11	Tech_Surv_26	15	5,4	0,5	0,00*
4	When visual reference is not possible, a missing label is not a problem to exercise control in a safe and efficient way.	OP_Serv-04 OP_Perf-12 OP_Perf-11	Tech_Gen_28 Tech_Surv_03	15	2,9	1,1	0,07
5	When visual reference is not	OP_Serv-11	Tech_Gen_28	14	3,4	1,3	0,85

VA-Id.	Questionnaire Item	ORD / HMI	TRD	N	Mean	SD	p
	possible, a missing position report is not a problem to exercise control in a safe and efficient way.	OP_Serv-04 OP_Perf-12 OP_Perf-11	Tech_Surv_03				
	Comment by ATCO M: hasn't happened.						
6	When visual reference is not possible, a wrong label is not a problem to exercise control in a safe and efficient way.	OP_Serv-04 OP_Perf-11	Tech_Surv_03	15	1,9	1,1	0,00*
7	Very frequently I experienced track swapping.		Tech_Gen_28	15	3,4	1,2	0,75
8	When visual reference is not possible, track swapping prevents me to exercise control in a safe and efficient way.	OP_Perf-11 OP_Perf-13 OP_Perf-11	Tech_Gen_31 Tech_Gen_35 Tech_Gen_36	15	4,3	0,9	0,00*
15	I think manual labelling is useful.	HMI_REQ 3.1.1 #6 + #19	Tech_HMI_07	14	4,5	1,0	0,00*
	Comment by ATCO H: I haven't used it yet. Comment by ATCO O: It takes some time and label is often lost.						
16	I think that the A-SMGCS surveillance display could be used to determine that an aircraft has vacated the runway.	OP_Serv-11	Tech_Supp_03	15	5,3	0,5	0,00*
17	I think that the A-SMGCS surveillance display could be used to determine that an aircraft has crossed a holding position.	OP_Serv-11	Tech_Supp_03	15	4,5	1,3	0,01*
	Comment by ATCO F: The holding position is much more accurate (???) position then vacating RWY therefore I slightly agree.						
35	I think that the A-SMGCS surveillance display could be used to determine that an aircraft is on stand or has left the stand.	OP_Perf-05 OP_Serv-11	Tech_Surv_26	15	3,8	1,3	0,37
	Comment by ATCO F: it depends on quality of surveillance Comment by ATCO O: During LVO yes. Otherwise, I still prefer to look out of the window.						
89	I think there is too much inconsistency between A-SMGCS and real traffic.	OP_Serv-01 OP_Serv-03	Tech_Surv_34	15	2,5	1,0	0,00*
	Comment by ATCO K: But sometimes false targets.						
111	The A-SMGCS display gives me sufficient information about airborne traffic in the vicinity of the airport.	OP_Perf-07 OP_Serv-13	Tech_Surv_32 Tech_Surv_20	15	4,5	1,0	0,00*
	Comment by ATCO E: I rely more on E 2000.						

Table 4-4: Debriefing Questionnaire - Means, SD, and P-Value for "Surveillance" operational feasibility items

4.2.1.3 Control

VA-Id.	Questionnaire Item	ORD	TRD	N	Mean	SD	p
25	A-SMGCS helps to issue traffic information.		Tech_Surv_05 Tech_Gen_02	15	5,1	1,0	0,00*
26	A-SMGCS makes it easier to detect pilot errors.		Tech_Surv_05	15	5,2	0,8	0,00*
27	When visual reference is not possible, A-SMGCS facilitates to give traffic information to pilots so that they can avoid other traffic.	OP_Perf-5	Tech_Surv_26 Tech_Gen_02	15	4,9	0,5	0,00*
40	A-SMGCS display gives me better means to expedite or slow down an aircraft's taxi speed.		Tech_Surv_28	15	4,1	1,2	0,06
	Comment by ATCO D: I don't do it very often without (with) A-SMGCS.						
64	*Information alerts are often popping up too late to solve the situation before an alarm comes up.*		*Tech_Cont_13*	7	3,0	1,2	0,30
	Comment by ATCO L: In test – not used in real traffic.						
65	*Too many unnecessary information alerts were popping up.*	*Op_Perf-20*	*Tech_Cont_08* *Tech_HMI_15*	7	3,4	1,4	0,90
	Comment by ATCO L: In test – not used in real traffic. Comment by ATCO O: in case of false targets.						
66	*I think that all Runway Incursion Alerts are triggered at the right moment.*	*Op_Perf-20*	*Tech_Cont_13*	7	4,1	1,2	0,21
	Comment by ATCO L: In test – not used in real traffic.						
67	*I think that a Runway Incursion monitoring alert function helps me to react in an expeditious and safe manner.*	*OP_Serv-16*	*Tech_Cont_13* *Tech_Cont_03*	8	4,4	1,3	0,10
	Comment by ATCO K: The problem is that A-SMGCS display is not the ATCO's primary display. Comment by ATCO L: In test – not used in real traffic.						
68	*I experienced too many false alerts to work in a safe and efficient way.*	*OP_Perf-20* *OP_Perf-21*	*Tech_Cont_12*	8	3,1	0,8	0,24
	Comment by ATCO L: In test – not used in real traffic.						
69	*There were cases where an alarm was missing.*		*Tech_Cont_02*	8	2,9	1,4	0,23
	Comment by ATCO L: In test – not used in real traffic.						
77	Issuing clearances to aircraft is supported well by the A-SMGCS.	OP_Serv-14	Tech_Gen_02	15	4,5	1,0	0,00*
79	The information displayed in the A-SMGCS is helpful for avoiding conflicts.	OP_Serv-21 OP_Serv-30 OP_DS-6	Tech_Surv_05	15	5,1	0,7	0,00*
123	The A-SMGCS enables me to provide the	OP_Serv-14	Tech_Gen_02	15	4,4	1,5	0,03*

VA-Id.	Questionnaire Item	ORD	TRD	N	Mean	SD	p
	pilots a better level of service.						
	Comment by ATCO E: Not in normal condition. Within LVP traffic information are given.						

Table 4-5: Debriefing Questionnaire - Means, SD, and P-Value for "Control" operational feasibility items

4.2.1.4 HMI

VA-Id.	Questionnaire Item	D135_ORD D136_HMI	N	Mean	SD	p
75	The A-SMGCS provides the right information at the right time.	Op_Serv-30	15	5,1	0,6	0,00*
81	Improvements in the A-SMGCS display would be desirable.		15	3,7	1,0	0,36
83	The display enables to recognize a degrading accuracy of surveillance.		13	3,6	1,2	0,73
84	The display layout is easy to customize to my own preferences.	REQ 3.1.1 #2 + #18	15	4,7	0,7	0,00*
88	I think the A-SMGCS is easy to use.	Op_If-1	15	4,9	0,7	0,00*
90	I find the A-SMGCS very difficult to use.	Op_If-1	15	1,9	1,0	0,00*
91	The use of the different windows on the A-SMGCS display is clear to me.	Op_If-1	15	4,8	0,6	0,00*
92	Too much interaction with the A-SMGCS is needed.	Op_If-1	15	2,9	0,8	0,01*
93	The A-SMGCS display is easy to understand.	Op_If-1	15	5,0	0,4	0,00*
94	The A-SMGCS display provides an active, involved role for me.	Op_If-1	15	4,7	0,6	0,00*
96	Information is conveniently arranged in the A-SMGCS display.	Op_If-1	15	4,7	0,5	0,00*
97	The amount of information in the A-SMGCS display is not too large.	Op_If-1	15	4,4	1,2	0,01*
98	Symbols can easily be read under different angles of view in the A-SMGCS display.	Op_If-1	15	5,1	0,6	0,00*
99	Labels, signs, and symbols in the A-SMGCS display are easy to interpret.	REQ 3.1.1 #15 + #16 + #17 REQ 3.2.4# 4 Op_If-1	15	5,0	0,5	0,00*
100	The height and width of characters in the A-SMGCS display is sufficient.	Op_If-1	15	5,0	0,7	0,00*
101	The A-SMGCS display layout in general should not be changed.	Op_If-1	15	4,5	1,1	0,00*

VA-Id.	Questionnaire Item	D135_ORD D136_HMI	N	Mean	SD	p
102	The A-SMGCS display size is appropriate for daily work.	Op_If-1	15	5,1	0,5	0,00*
103	All text in the display is easy to read.	Op_If-1	15	4,7	1,0	0,00*
	Comment by ATCO E: ARR + DEP windows are difficult to read (not often used in real traffic). Comment by ATCO G: When yellow (?) alert is on the colour of box and text inside the box is not very well combined,					
104	There is too much information in the A-SMGCS display which is not needed.	Op_If-1	15	2,5	0,7	0,00*
	Comment by ATCO E: Can be set up at personal feelings.					
105	Some relevant information is frequently missing in the A-SMGCS display.	Op_If-1	15	2,7	1,3	0,03*
	Comment by ATCO D: Labels on the end of screen. Comment by ATCO G: Designation of temporary maps window, when you open the window you don't know which of the maps is used. Comment by ATCO K: Departing aircraft in DEP window Comment by ATCO L: Some missing aircraft in departure list while aircraft is ready to go -> manual labelling impossible.					
106	The display colours chosen in the A-SMGCS display are appropriate.	REQ 3.1.1#13 Op_If-1	15	4,9	0,5	0,00*
107	Pop-up windows appear at the expected place and size.	Op_If-1	15	4,1	1,4	0,15
	Comment by ATCO K: Pop-up window referring to time to threshold is not visible in certain situations (THD (?) is close to window edge). Comment by ATCO O: When RWY 13 is in use (not often) -> when a pop-up window (arrival) appears, it hides a label of departure that holds short of RWY 13 on RWY 24. It is necessary to open secondary window to get the information.					
108	The windows on the A-SMGCS display are conveniently arranged.	Op_If-1	14	4,6	0,7	0,00*
	Comment by ATCO O: (except for the pop-up window of arrival on RWY 13 – see item 107)					
109	Aircraft that should have been visible are sometimes obscured by pop-up windows.	REQ 3.1.1 #14	15	3,5	1,1	0,91
	Comment by ATCO O: (except for the pop-up window of arrival on RWY 13 – see item 107)					
110	The contrast between the windows and their background is sufficient.		15	5,0	0,4	0,00*
130	The A-SMGCS display is detracting too much attention.	Op_If-1	15	2,7	1,1	0,01*
	Comment by ATCO O: not the display itself; it is sometimes forgotten to operate the function of blocked RWY, especially in heavy traffic (we are used to a different indication) and it can lead to a situation when reality is different from what is indicated on display.					
131	The A-SMGCS display helps to have a better understanding of the situation.	REQ 3.1.1 #9 + #15	5	5,0	0,7	0,01*
132	Important events on the A-SMGCS were difficult to recognize.	REQ 3.1.1 #13 + #14 + #17 + #23 + #27 Op_If-1	15	2,3	0,6	0,00*

VA-Id.	Questionnaire Item	D135_ORD D136_HMI	N	Mean	SD	p
133	Sometimes information is display, which I don't need.	REQ 3.1.1 #12 + #14 + #15 ? Op_If-1	15	3,1	0,8	0,05
134	Different colour codes on the A-SMGCS display are easy to interpret.	(REQ 3.1.1 #13) Op_If-1	15	5,0	0,4	0,00*

Table 4-6: Debriefing Questionnaire - Means, SD, and P-Value for "HMI" operational feasibility items

4.2.1.5 Procedures

VA-Id.	Procedure	ORD sections	N	Mean	SD	p
18	**Contingency A-SMGCS surveillance identification procedures** I think when the SMR completely fails but MLAT remains the A-SMGCS display cannot be used as a primary means for identification anymore.	4.2.2	12	3,5	1,0	1,00
	Comment by ATCO F: Depends on how many aircraft and vehicles are equipped with transponder. Comment by ATCO O: I have no experience with that					
19	When the direct recognition of aircraft/vehicle IDs through the label is no longer possible, due to a ground MLAT failure, the surveillance display should be downgraded to a lower level of surveillance, such as SMGCS surveillance display (e.g. labelled SMR) or SMR display only.	4.2.2	13	4,4	0,7	0,00*
	Comment by ATCO O: I have no experience with that					
20	I think an individual aircraft's failure to comply with A-SMGCS procedures (e.g. MODE-S transponder failure) requires returning completely to SMGCS procedures for all aircraft.	4.2.2	15	2,8	1,4	0,07
21	I think procedures in case of A-SMGCS failure are defined clear enough.	4.2.2	15	3,9	1,2	0,25
22	**Transponder Operating Procedures** I experienced that aircraft have failed to comply with the transponder operating procedures.	5.	15	4,7	0,9	0,00*
23	I think it is appropriate that pilots switch on the transponder before requesting pushback (or taxiing or whatever is earlier).	5.2.2	15	5,4	0,6	0,00*
24	I experienced that pilots have failed to turn the transponder on just prior to requesting push back (or taxiing or whatever is earlier).	5.2.2	15	4,7	0,9	0,00*

30	**Start-Up clearance delivery** The A-SMGCS surveillance display enables me to establish a more efficient start-up sequence in visibility 1 conditions.	8.1.2	14	2,8	1,3	0,06
	Comment by ATCO G: There is no such description in the system.					
31	The A-SMGCS surveillance display enables me to establish a more efficient start-up sequence in visibility 2 conditions.	8.1.2	14	2,8	1,1	0,03*
	Comment by ATCO G: There is no such description in the system.					
32	The A-SMGCS surveillance display enables me to establish a more efficient start-up sequence in visibility 3 conditions.	8.1.2	14	3,0	1,4	0,19
	Comment by ATCO G: There is no such description in the system.					
33	**Push-back clearances** When gates are not visible push-back clearances based on A-SMGCS traffic information can be given in a safe way.	8.1.3.2	15	4,2	0,8	0,00*
34	I think that traffic information on the A-SMGCS surveillance display helps me to decide whether a push-back clearance should be delayed.	8.1.3	15	4,1	0,8	0,02*
36	**Taxi clearances** I can rely on A-SMGCS when giving taxi clearances even when visual reference is not possible.	8.1.4.2	15	4,9	0,7	0,00*
	Comment by ATCO K: slightly disagree due to false targets					
37	Longitudinal spacing on taxiways is easier to survey with A-SMGCS even when visual reference is not possible.		15	4,9	0,6	0,00*
38	When visual reference is not possible I think longitudinal spacing on taxiways can be reduced with A-SMGCS.		15	4,7	1,3	0,00*
	Comment by ATCO L: … if approved by our authority, it would be great.					
44	**Taxiing on the runway** ICAO doc 4444 states that for the purpose of expediting air traffic, aircraft may be permitted to taxi on the runway-in-use. I think the use of A-SMGCS could allow this even when visual reference is not possible.	8.1.7.2	15	4,5	1,4	0,02*
48	**Line-up procedures** When an intersection is not visible, line-up from this intersection could be applied in a safe way when using A-SMGCS.	8.1.8.2.2	15	5,1	0,5	0,00*
49	I think it could practicable to make multiple line-ups using A-SMGCS when visual reference is not possible.	8.1.8.3.1.2	15	4,0	1,7	0,28

	Comment by ATCO G: Multiple line-ups when no visual are nonsense. Comment by ATCO L: … if approved by our authority, it would be great.					
54	**Take-off clearance** I think that the A-SMGCS surveillance display could be used to determine when to issue a take-off clearance.	8.1.9	15	4,5	1,4	0,02*
55	**Landing clearances** 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.	8.1.10.2	15	5,3	0,6	0,00*
56	**Conditional clearances** Under good visibility conditions I think A-SMGCS surveillance data helps me to give conditional clearances in a safe and efficient way.	8.1.11	15	4,0	1,6	0,23
	Comment by ATCO O: Not only the A-SMGCS.					
57	When visual reference is not possible, I think A-SMGCS surveillance data helps me to give conditional clearances in a safe and efficient way.	8.1.11 8.1.11.2	15	4,1	1,5	0,13
	Comment by ATCO G: When no visual reference = no conditional clearances Comment by ATCO O: Not only the A-SMGCS.					
60	**Visibility Transition** With A-SMGCS, it would make sense to redefine the visibility limits for the transition to low visibility operations. (if yes, please indicate your suggestions)	6.	12	2,3	0,9	0,00*
	Comment by ATCO C: The time between arrivals and departures would be shorter, we shouldn't wait for "runway vacated" report, and the distance between two arrivals could be shorter. Comment by ATCO F: In a process to redefine visibility limits is A-SMGCS ok only one part. Comment by ATCO G: Visibility limits are for pilots.					
63	**A-SMGCS level 2 procedures** I think A-SMGCS can help me to detect lit stop bar crossings.	8.2	14	4,9	0,7	0,00*
63a	I think A-SMGCS can help me to detect runway incursions.					
70	**A-SMGCS level I & II phraseology** Existing phraseology can be maintained without change while using A-SMGCS.	7. 7.1.3	14	4,7	0,6	0,00*
71	I have experienced situations where existing phraseology should have been changed while using A-SMGCS.	7.1.3 12.1.	14	2,8	1,2	0,04*
	Comment by ATCO F: e.g. squawk assigned code – some pilots do not understand					

Table 4-7: Debriefing Questionnaire - Means, SD, and P-Value for "Procedure" operational feasibility items

4.2.2 Long Term Alerting Performance Assessment

The objective of this test was to assess the operational feasibility of the alerting function. Technically the function's performance has been verified (cf. 2.3.12, 2.3.13, and 2.3.14) but the controllers' acceptance has not been assessed in the field. For this purpose the monitoring and alerting function was switched on at the active CWP for more than two weeks in January 2006. But, the service was not used fully operational[16] but only used to be monitored by controllers in case of a conflict situation.

To assess the operational performance the controllers were requested to report each conflict situation and to compare it with the alerts shown on the A-SMGCS display. They were requested to report the date and UTC and to assess whether the alert was right (wanted), false (due to a false target), unwanted, or missed. Information (stage 1) alerts was not assessed to reduce the additional workload of the controller. The reporting sheet was developed with support of an ANS_CR controller and translated to Czech language to get easier the controllers' acceptance to perform this additional work.

Following template has been given to the controller:

Date	UTC	Stage 2 alert (red)			false	unwanted	missed
		too early	right	too late			

Instructions:
The objective of this sheet of paper is to assess the performance of the A-SMGCS alerting function and to adapt it to your needs. For this purpose, we need your operational feedback. Therefore, it is very important that you monitor all alerts on your A-SMGCS display the whole time you are working with it.

There are two stages of alerts. The stage 1 alert (amber) intends to attract your attention on a traffic situation that is potentially dangerous, e.g. two aircraft on the runway, one is lining up while another one is just vacating. The stage two alert (red) would require an immediate reaction by you to solve a actual conflict situation. You are questioned to red alerts only.

*If you see such red stage 2 alerts on your A-SMGCS display you are kindly requested to give your personal assessment to it. If the alert is wanted by you, you should assess if the alert was **too early**, **right in time**, or **too late** to help you in the best way.*

*If an alert is raised due to a false surveillance target, please make a cross with **false**.*

*If an alert is raised although there is no conflict situation that would need your special attention, make a cross with **unwanted**.*

*Last, if you are confronted with a real conflict situation but the system did not raise an alert or information, make a cross with **missed**.*

*Do not forget to note the **Date** and **UTC** time.*

If you find time we would really appreciated if you write some explanations to the experienced conflict situation, e.g. CSA456 landed on RWY24 but missed exit C and was still at the runway when following

[16] With visibility conditions lower than 3000m, the service had to be switched off.

landing CSA3267 was 30 seconds from threshold. This will help us additionally to tune the system alerts to your operational needs.

Thank You for your collaboration.

Concluding Results

As it happened, the template could not been filled out by the controllers. This was caused by several reasons: First, the controller did not accept the additional workload or simply forgot to report an observed conflict situation. Secondly, the A-SMGCS display is not the primary display that is observed by the TEC but the E2000. Alerts that are displayed on the A-SMGCS display are not supported by an audible signal and thus could easily miss the controller's attention.

Concluding, no results were gained with this test.

4.2.3 Flight Tests - Case Studies for Testing the Alert Performance of "Crossing Runway Alerts"

These trials were performed on five days during the field trials (cf. the protocols with section 4.2.3). Each trial lasted approximately one hour with five to 12 conflict situations.

Case studies mean that during the regular traffic (at times of very less traffic amount) test vehicle or test aircraft cause safety critical scenarios to issue system alerts. The controllers who actively controlled the traffic were presented with these alerts and were asked afterwards for their views on the operational feasibility. The detailed conflict scenarios can be seen in the annex 6.1.

Four different runway crossing scenarios have been tested:

- departure – departure,
- departure – arrival,
- departure – crossing, and
- approach – approach conflicts

The first three departure conflicts could be tested by using a test car and the regular approaching or departing traffic. For the tests of the approach – approach conflicts, test aircraft had to be used. There were two CAA aircraft, a BE 400 and an L 410.

The following test protocols (4.2.3.1) give a complete report of these case studies, whereas section 4.2.3.2 summarises the results.

4.2.3.1 Raw Data – Flight Tests Protocols

Date:	2006-01-17
Test Run Number:	1
Name:	Tykal / Jakobi
Active vs. Shadow Mode	Shadow Mode

General Comments / Conditions:

- Test car and regular traffic were used
- Alerts were observed at the test bed Tower platform on the EMMA A-SMGCS by a former ANS_CR controller

- With EMMA alert settings, only two conflicting <u>aircraft</u> issue a crossing runway alert (wanted)
  - o Therefore, the EMMA vehicle had to be seen as an aircraft by the system to conduct the test with test vehicles.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	Stage 2 alert (red)			
								too early	right	too late	missed
11:03	EMMA	31		CSA880	24				x		

Comments:
- Targets turned to amber alert, when they commenced take-off (both were moving) and turned to red alert when the speed was higher than 20kts
- Alert was resolved when CSA880 passed the RWY31 intersection (diverging targets)

11:05	EMMA	31		GWI772P			Fox31				x

Comments:
- There was no alert issued
- The reason for this failure was probably a surveillance failure because the EMMA vehicle had two targets suddenly whereas one was interpreted as airborne by the system

11:14	EMMA	31		NAX1514			Fox31		x		

Comments:
- Worked fine

11:15	EMMA	31		AZA512			Fox31		x		

Comments:
- Worked fine

11:17	EMMA	31		CSA72C	24				x		

Comments:
- Worked fine

11:24	EMMA	31		AZA517	24				x		

Comments:
- Worked fine

Date:	2006-01-18
Test Run Number:	2
Name:	Tykal / Jakobi
Active vs. Shadow Mode	Active

General Comments / Conditions:

- EMMA A-SMGCS was running now on the real TPC CWP – other CWP run with the commercial A-SMGCS
- EMMA vehicle had a permanent speed between 40 and 55 kts
- EMMA vehicle was defined again as a departure aircraft within the system.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	Stage 2 alert (red) too early	right	too late	missed
11:09	EMMA	31		CSA2KL	24 B				x		

Comments:

- When EMMA started and speed was higher than 20kts amber stage 1 alert arose for 2 second that was substituted by a stage 2 alert

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
11:13	EMMA	31		AZA517	24				x		

Comments:

- When EMMA started and speed was higher than 20kts amber stage 1 alert arose for 2 second that was substituted by a stage 2 alert

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
11:17	EMMA	31		CSA72C	24				x		

Comments:

- Worked fine

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
11:21	EMMA	31		CSA28W	24 B				x		

Comments:

- Worked fine

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
11:27	EMMA	31		DLH94X		24					

Comments:

- Invalid: problems with snow ploughs on RWY 22 that worked within the sensitivity area of RWY31 and caused a stage 2 alert with the "EMMA" vehicle

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
11:32	EMMA	31		NJE983Q		24			x		

Comments:

- EMMA started moving when NJE983Q was 75 sec away from threshold
- Stage 1 alert – off –stage 1 alert – stage 2 alert when aircraft was less than 30 seconds away from threshold
- Probably, flight test with real aircraft that have higher speeds and a constant deceleration and not a constant speed as the test car

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
11:34	EMMA	31		AZA512		24			x		

Comments:

- Worked fine, even when alert varied from stage 1 to off and to stage 2 again

11:43	EMMA	31		CSA961		24			x		

Comments:

- Stage 1 until CSA 961 was less than 30sec away from threshold when it stage 1 switched to stage 2
- When speed of the car was lower than 20kts alert was cancelled

11:48	EMMA	31		EXS195			Fox31		x		
11:48	EMMA	31		CSA790	24				x		

Comments:

- EMMA vehicle departure + Crossing + Departure 24 at the same time
- Both alerts worked well – all 3 labels were red (stage 2 alert)

11:52	EMMA	31		SAS1767		24			x		

Comments:

- Worked fine, even when alert varied from stage 1 to stage 2 when SAS1767 was 45 sec away from threshold

Date:	2006-01-23
Test Run Number:	3
Name:	Tykal / Jakobi
Active vs. Shadow Mode	Active

General Comments / Conditions:

- Flight tests with two CAA test aircraft CBA40 (BE40) and CBA41 (L410) concentrated on Approach – Approach conflicts exclusively, because this conflict could not be tested with test cars the week before
- CPA has been reduced by ANS_CR from 900 to 700 meter but TCPA increased from 75 to 80 seconds that stage alert arises appr. 45 seconds before threshold
- Alerts worked fine, but probably still to early – TCPA will be switched back to 75 sec for the next day

UTC	**Mov1**	DEP	APP	**Mov2**	DEP	APP	Cross	**Stage 2 alert (red)**			
								too early	right	too late	missed
12:30	CBA40		24	CBA41		31		x			

Comments:

- Stage one alert with 60sec from threshold, stage 2 with 45 sec
- CBA41 did a left turn, CBA40 an overshoot

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
12:43	CBA40		06	CBA41		31					x

Comments:

- Stage 1 alert with 60sec but disappeared with 45 sec
- Speed probably too low to meet TCPA

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
12:54	CBA40		24	CBA41		13					x

Comments:

- Neither stage 1 nor stage 2 alert
- CBA41 passed the crossing area when CBA41 was more than 700 meters away from this crossing area

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
13:05	CBA40		24	CBA41		31			x		

Comments:

- Stage 1 with 75 to 60 sec, stage 2 from 60, 45, and 30 sec

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
13:12	OKLMR	31		PTACNIK			31		x		

Comments:

- Not planned but crossing stage 2 alert worked fine

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
13:16	CBA40		06	CBA41		31			x		

Comments:

- No stage 1 alert
- Stage 2 alert after 60, 45, and 30 sec

13:29	CBA40		24	CBA41		13			x		

Comments:

- Stage 1 and stage 2 alert started after 75 sec and changed several times from stage 1 to stage 2 and back
- CBA40 landed and CBA41 flew a go-around by a right turn.

Date:	2006-01-24
Test Run Number:	4
Observer:	Tykal / Jakobi
TPC –TEC:	IS / ZH
Active vs. Shadow Mode	Active

General Comments / Conditions:

- Same test scenario as the day before
- TCPA has been tuned again:
    - stage 1: 90 sec
    - Stage 2: 75 sec

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	Stage 2 alert (red)			
								too early	right	too late	missed
08:32	Squawk 3311			OKWDC	31				x		

Comments:

- Target – most probably a helicopter – turned around the north of RWY 24
- Alert recordings detected an “opposite traffic on the runway” conflict

12:17	CBA40		24	CBA41		31					x

Comments:

- Neither stage 1 nor stage 2 alert
- System calculates no point of closest approach closer than 700 m within 90 sec or that CBA41 achieves the crossing area within 120 sec (TTX = 120 sec)
- Speed of CBA41 was very low (130kts) and too far away from threshold to initialize an alert with the current alert settings
- But alert or at least information is wanted.

12:29	CBA40		06	CBA41		31			x		

Comments:

- Stage 1 alert with 60 sec for CBA40 and 45 sec for CBA41
- After 2 seconds stage 2 alert with 60 sec for CBA40 and 45 sec for CBA41 away from threshold.

12:39	CBA40		24	CBA41		13			x		

Comments:

- Stage 1 alert with 90 sec for CBA40 and 75 sec for CBA41
- Disappeared for 2 seconds but reappeared immediately
- Stage 2 alert with 60 sec for CBA40 and 45 sec for CBA41 away from threshold.

12:48	CBA40		24	CBA41		31			x		

Comments:

- Stage 1 alert with 75 sec for CBA40 and 45 sec for CBA41
- Disappeared for 2 seconds but reappeared as stage 2 alert with 60 sec for CBA40 and 45 sec for CBA41 away from threshold.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	Stage 2 alert (red)			
								too early	right	too late	missed
12:57	CBA40		06	CBA41		31			x		

Comments:

- 3315 helicopter has flown in the north of RWY24 and caused stage 2 alert with CBA41 when CBA41 was ≥90 seconds away from threshold
- Stage 1 alert with 75 sec for CBA40 and 60 sec for CBA41
- Switched back to stage2 alert with helicopter meanwhile CBA40 remained amber coloured (stage 1)
- Stage 2 alert with 60 sec for CBA40 and 45 sec for CBA41 away from threshold.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
13:11	CBA40		24	CBA41		13			X		

Comments:

- Stage 1 alert with 45 sec for CBA40 and 60 sec for CBA41
- Stage 2 alert with 30 sec for CBA40 and 45 sec for CBA41 away from threshold.

Date:	2006-01-25
Test Run Number:	5
Observer:	Tykal / Jakobi
TPC –TEC:	Non- EMMA controller
Active vs. Shadow Mode	Active

General Comments / Conditions:

- TCPA has seen tuned for stage 1 alert to get it earlier
  - Stage1 TCPA is now 100 sec (yesterday 90 sec)
- DEP – APP Conflicts are tested with a test vehicle to investigate the new settings from 10:00 to 11:00
- from 12:00 to 13:00 APP-APP conflicts are tested with the two CAA test aircraft

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	Stage 2 alert (red)			
								too early	right	too late	missed
10:06	EMMA	31		CSA505			31		x		

Comments:

- Stage 1 followed by a stage 2 alert

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
10:08	EMMA	31		CSA617		24			x		

Comments:

- 24 EMMA stated when arriving was very close to the 24 threshold
- Stage 2 alert arose immediately when aircraft was 30 sec away from threshold.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
10:13	EMMA	31		BAW 854		24			x		

Comments:

- Stage 2 alert but when speed Sid already braked on RWY24
- Vehicle went with constant 60kts which was too slow to meet CPA within TCPA.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
10:15	EMMA	31		BAW854			31		X		

Comments:

- Stage 1 followed by a stage 2 alert.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
10:19	EMMA	31		CLW9019		24			x		

Comments:

- EMMA vehicle now starts from RWY22 intersection
- Stage 2 alert when CLW 45 seconds away.

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
10:21	EMMA	31		LOT523		24			x		

Comments:

UTC	Mov1	DEP	APP	Mov2	DEP	APP	Cross	too early	right	too late	missed
10:23	EMMA	31		CSA961		24			x		

Comments:

- Stage 1 alert with 45 sec away from threshold, followed by a stage 2 alert when CSA961 was less than 45 seconds away from threshold.

10:24	EMMA	31		LOT523			31		x		
10:27	EMMA	31		DAT67F		24			x		

Comments:

10:31	EZY5494	24		CSA842	13			UNWANTED			

Comments:

- Both aircraft started take-off at the same time but in different directions where they never would meet
- Stage 1 and stage 2 alert were popping up, even when the EZY5494 has passed RWY 31/13
- UNWANTED alert
- Probably there is no CPA criteria but only speed (to be checked)

10:43	EMMA	31		KLM1352	24B				x		

Comments:

- EMMA started late (after KLM has commenced its take-off)
- But worked well – with 20kts stage 1 alert, with 40kts car speed stage 2 alert popped up.

10:45	EMMA	31		CSA916	24				x		

Comments:

- Departure alerts seems to be working fine and reliable
- 20kts – stage 1; 40kts – stage 2

10:49	EMMA	31		CSA977		24			x		

Comments:

- Stage 1 with 45 sec and stage 2 below 45 sec

12:01	CSA962	13		CSA050	24B			UNWANTED			

Comments:

- Simultaneous take-off but with diverging directions
- UNWANTED alert

12:22	CBA40		24	CBA41		31			x		

Comments:

- Stage 1: CBA40 75 – CBA41 75 sec
- Stage 2: CBA40 45 – CBA41 45 sec
- This timing is absolutely wanted

12:24	EMMA	31		BMI88X			31		x		

Comments:

- EMMA vehicle, which is still seen as an aircraft by the system, taxied on RWY31 and caused an alert (stage 2) with the crossing BMI88X.

12:33	CBA40		06	CBA41		31			x		

Comments:

- Stage 1: 90-60 sec
- Stage 2: 75-30 sec

12:49	CBA40		24	CBA41		13				x	

Comments:

- Stage 1: no stage 1 alert (CBA41
- Stage 2: 30-45 sec
- Stage 2 alert is probably a bit to late – TCPA should be increased from 75 sec to 80 seconds, eventually (to be discussed).

13:00	CBA40		24	CBA41		31			x		

Comments:

- Stage 1: 75-75 sec
- Stage 2: 45-45 sec

13:10	CBA40		06	CBA41		31			x		

Comments:

- Stage 1: no stage 1 alert but stage 2 was fine
- Stage 2: 45-30 sec

13:22	CBA40		24	CBA41		13			x		

Comments:

- Stage 1: 60-90 sec
- Stage 2: 45-45 sec
- Perfect

4.2.3.2 Results

In total 50 conflict situation have been tested with very satisfying results (cf. Table 4-8). There were only 4% of unwanted alerts and 10% of missed alerts, which seems to be a bit too much to assess it as operationally acceptable but the results do not reflect the full operational alert performance because the tests were also used to tune new alert parameter settings. At the end of the trials, the best setting was found so that the assumption can be made that further tests would increase the percentage of right alerts compared to unwanted and missed alerts.

Conflict	**Stage 2 alert (red)**					
	too early	**right**	**too late**	**missed**	**unwanted**	
DEP - DEP	0	10	0	0	2	12
DEP - APP	0	11	0	0	0	11
DEP - CROSS	0	7	0	3	0	10
APP - APP	1	13	1	2	0	17
	1	41	1	5	2	50
	2%	**82%**	**2%**	**10%**	**4%**	**100%**

Table 4-8: Alert Performance Results with Crossing Runway Conflicts

The alert setting "evolution" can be seen with Table 4-9. However, these settings are only valid for Prague purposes and for a special system design. They will have to be developed and adapted when an alert function is being tuned for another airport.

		30.11.05	16.1.06	20.1.06	24.1.06	25.1.06
TTX	**sec**	100	100	120	120	120
Min. speed	**m/s**	10	10	10	10	10
TCPA Stage1	**sec**	90	90	95	90	100
CPA Stage1	**m**	1200	950	700	700	700
TCPA Stage2	**sec**	75	75	80	75	75
CPA Stage2	**m**	1200	950	700	700	700
Abbreviations: TTX = Time for arrival aircraft to crossing area TCPA = Time to Closest Point of Approach) CPA = Closest Point of Approach						

Table 4-9: Alert Parameter Setting for the Runway Crossing Alerts for different days of the Flight Tests

4.3 Operational Improvements (Field Trials)

With the operational feasibility tests (4.2), full sets of performance/operational requirements and procedures have been tested for their operational feasibility. To fully validate a system it must also show that new services and procedures contribute to an operational improvement. There are four areas of interest to measure these operational improvements:

- Safety
- Capacity (in terms of throughput)
- Efficiency
- Human Factors aspects

The following general hypotheses had been set up to describe the expectation with the controllers' answers with respect to the "operational improvement":

Identifier	Hypothesis
OI-SAF3-H0	The controllers' opinion does not agree to the "safety" aspects expressed by a specific safety item.
OI-SAF3-H1	The controllers' opinion agrees to the "safety" aspects expressed by a specific safety item.

OI-EFF6-H0	The controllers' opinion does not agree to the "efficiency/capacity" aspects expressed by a specific safety item.
OI-EFF6-H1	The controllers' opinion agrees to the "efficiency/capacity" aspects expressed by a specific safety item.

OI-HF5-H0	The controllers' opinion does not agree to the "Human Factors" aspects expressed by a specific safety item.
OI-HF5-H1	The controllers' opinion agrees to the "Human Factors" aspects expressed by a specific safety item.

4.3.1 Debriefing Questionnaire (operational improvements)

As already outlined with section 4.2.1, the a 144 items questionnaire and a t-test for the statistical analyses has been used:

- One-Sample T-Test
- Expected mean value = 3,5
- Answers from 1 (disagreement) through 6 (agreement)
- N = 15
- $\alpha = 0.05$
- p-value is on single sided because of the use of directed hypothesis

The items referring the "operational improvement" and their results are reported in the following sections 4.3.1.1 "Safety", 4.3.1.2 "Efficiency/Capacity, and in section 4.3.1.3 "Human Factors".

A star (*) attached to the p-value means that a questionnaire item has been answered significantly because the p-value is equal or less than the critical error probability α, which is 0.05. Additionally, such items are coloured green.

When the controllers significantly express their acceptance to a single service or procedure item, it can be assumed that the operational feasibility is proven.

Items written in italics could not be answered meaningfully because the controllers had limited or no operational experience with the topic (e.g. except in the case of lit stop bar crossing, no system alerts have been used operationally by the ATCOs). When controller comments were given to an item, they are reported directly below the statement.

4.3.1.1 Safety

VA-Id.	Questionnaire Item	N	Mean	SD	p
28	When procedures for LVO are put into action, A-SMGCS helps me to operate safer.	15	5,4	0,5	0,00*
50	A-SMGCS is helpful for better monitoring aircraft commencing it's take off roll.	15	5,0	1,3	0,00*
61	I think A-SMGCS can help me to detect or prevent runway incursions.	13	4,9	1,0	0,00*
62	I think A-SMGCS can help me to detect or prevent incursions into restricted areas.	13	5,0	0,8	0,00*
120	The use of A-SMGCS endangers safety at the airport.	10	2,1	1,2	0,00*
129	There is a risk of focusing too much on a single problem when using A-SMGCS.	10	2,9	1,1	0,12

Table 4-10: Debriefing Questionnaire - Means, SD, and P-Value for "Safety" operational improvement items

4.3.1.2 Efficiency/Capacity

VA-Id.	Questionnaire Item	N	Mean	SD	p
9	When visual reference is not possible, I think identifying an aircraft or vehicle is more efficient when using the surveillance display.	15	5,2	1,3	0,00*
10	I think, also in good visibility conditions, identifying an aircraft or vehicle is even more efficient when using the surveillance display.	15	5,2	0,6	0,00*
11	Recognition of the aircraft type is more efficient with A-SMGCS.	15	5,0	1,1	0,00*
	Comment by ATCO F: depends on information in a label. When I have a type in a label then I agree. Comment by ATCO K: If real type is identified with flight plan one.				
29	When procedures for LVO are put into action, A-SMGCS helps me to operate more efficiently.	15	5,2	0,8	0,00*
38	When visual reference is not possible I think longitudinal spacing on taxiways can be reduced with A-SMGCS.	15	4,7	1,3	0,00*
39	Without visual reference but using A-SMGCS, it would no longer be necessary to make records of vehicles on the manoeuvring area.	15	3,8	1,2	0,35

41	Coordination between involved control positions is more efficient with A-SMGCS.	10	4,5	1,1	0,00*
42	With A-SMGCS hand over processes between different control positions are more efficient.	15	4,6	1,3	0,03*
	Comment by ATCO F: We have not hand over procedures so? Comment by ATCO H: hand over procedures not applicable				
43	The number of position reports will be reduced when using A-SMGCS (e.g. aircraft vacating runway-in-use).	15	4,9	0,7	0,00*
45	In good visibility line-up at the runway threshold is easier to control with A-SMGCS.	15	4,7	1,0	0,00*
46	When the runway threshold is not visible line-up is easier to control with A-SMGCS.	15	5,3	0,5	0,00*
47	In good visibility line-up from intersection is easier to control with A-SMGCS.	14	4,7	1,3	0,00*
51	With A-SMGCS, a clearance for a rolled take-off can be issued more frequently.	15	4,6	0,9	0,00*
52	In good visibility take-offs from intersection are easier to control with A-SMGCS.	15	4,5	1,1	0,00*
53	When an intersection is not visible take-offs from the intersection are easier to control with A-SMGCS.	15	5,1	0,6	0,00*
58	The transition from normal operations to low visibility operations is easier with A-SMGCS.	15	4,9	0,9	0,00*
72	The control of aircraft with the A-SMGCS is very efficient.	15	5,1	0,8	0,00*
74	A-SMGCS reduces waiting times for aircraft at the airport.	15	3,9	1,5	0,35
112	With A-SMGCS, it is easier to separate aircraft safely.	15	4,9	1,0	0,00*
	Comment by ATCO E: Not in the air				
113	With A-SMGCS, it is easier to detect runway incursions.	14	4,9	1,2	0,00*
	Comment by ATCO E: Not if warnings are not on. (not used in Prague)				
114	With A-SMGCS, it is easier to detect incursions into closed taxiways.	13	4,8	1,3	0,00*
	Comment by ATCO E: Not if warnings are not on. (not used in Prague) Comment by ATCO F: Not applicable				
115	With A-SMGCS, it is easier to detect incursions into protected areas.	15	4,8	1,3	0,00*
	Comment by ATCO E: Not if warnings are not on. (not used in Prague)				
116	With A-SMGCS, it is easier to detect aircraft on the apron.	15	4,5	1,1	0,00*
	Comment by ATCO E: Apron in common settings is suppressed.				

121	I think that the A-SMGCS increases traffic throughput at the airport.	15	4,0	1,1	0,22
121a	*When the traffic demand is higher than the current capacity I think with A-SMGCS the traffic throughput can be increase.*	5	*3,4*	*1,5*	*0,89*
122	The A-SMGCS enables me to handle more traffic when visual reference is not possible.	15	4,3	1,1	0,01*
124	The A-SMGCS enables me to execute my tasks more efficiently.	14	4,5	1,1	0,00*
128	There are less frequent unexpected calls of A/C and vehicles with A-SMGCS.	12	3,4	1,3	0,84
137	The use of A-SMGCS facilitates information gathering and interpretation.	15	4,6	0,7	0,00*

Table 4-11: Debriefing Questionnaire - Means, SD, and P-Value for "Efficiency/Capacity" operational improvement items

4.3.1.3 Human Factors

4.3.1.3.1 Situation Awareness

VA-Id.	Questionnaire Item	N	Mean	SD	p
12	The A-SMGCS display gives me a better position situational awareness (where is the traffic).	15	5,4	0,5	0,00*
13	The A-SMGCS display gives me a better identification situational awareness (who is who).	15	5,3	0,6	0,00*
125	The A-SMGCS helps me to maintain good situation awareness.	15	5,2	0,4	0,00*
126	"Maintaining the Picture" is supported well by the A-SMGCS.	15	4,9	0,5	0,00*
127	I feel that A-SMGCS enables me to predict better the evolution of the traffic (to be ahead of the traffic).	15	4,4	1,0	0,00*
131	The A-SMGCS display helps to have a better understanding of the situation.	15	5,2	0,4	0,00*

Table 4-12: Debriefing Questionnaire - Means, SD, and P-Value for "Situation Awareness" operational improvement items

4.3.1.3.2 Workload

VA-Id.	Questionnaire Item	N	Mean	SD	p
14	I think identifying the traffic using A-SMGCS increases workload.	15	2,1	1,3	0,00*
59	When procedures for LVO are put into action, A-SMGCS helps me to reduce my workload.	15	5,2	0,6	0,00*

73	The use of A-SMGCS makes the controller's job more difficult.	15	1,7	0,5	0,00*
76	The use of A-SMGCS has a negative effect on job satisfaction.	15	1,5	0,5	0,00*
138	The use of A-SMGCS increases mental effort for checking information sources.	14	2,4	0,9	0,00*
139	The use of A-SMGCS decreases workload for anticipating future traffic situations.	15	4,7	0,6	0,00*

Table 4-13: Debriefing Questionnaire - Means, SD, and P-Value for "Workload" operational improvement items

4.3.1.3.3 Human Error

VA-Id.	Questionnaire Item	N	Mean	SD	p
118	The introduction of the A-SMGCS decreases the potential of human error.	14	2,7	1,4	0,05
119	The introduction of the A-SMGCS is associated with new types of human error.	13	3,1	1,1	0,20
	Comment by ATCO M: Aircraft at holding point with mixed up labels can lead to calling wrong aircraft. Comment by ATCO O: see item 107				
136	The A-SMGCS is useful for reducing mental workload.	15	4,8	0,7	0,00*

Table 4-14: Debriefing Questionnaire - Means, SD, and P-Value for "Human Error" operational improvement items

4.4 Daily Observations

At each day of the operational field trials, protocols were created to gather all observations and comments given by the controllers and technicians. The following sections, which are sorted by the date, outline these results.

3rd November 2005

- At the old Tower there are 4 EMMA A-SMGCS CWPs now (incl. Gap Filler and updated HMI)
- Information (yellow) when two movements are within the runway sensitivity area – is wanted and happens when arriving aircraft is still on the runway and another one is lining up behind
- Time Arrival Windows is still "less than 30 seconds" and not "at least 30 seconds" – will be corrected with the new software update
- ATCO C said: the system is very useful for him, and as the system was not useable due to maintenance, he said he recognised that he was used to work head down only
- Labels sometimes overlap, but the controller can manually move them
- GA on intersection take off Bravo without label (no transponder)
- ATCO E and F said: In LVP they ask aircraft number 2 if it can see number 1. If yes, they allow two aircraft in one taxiway segment. If not, no clearance. But, with A-SMGCS this rule

could be softened. Probably, a safety net around the aircraft to warn the controller of movements that approach each other.

16th of January 2006

Weather conditions

- Snow but
- Runways and taxiways are cleared from snow
- LVO in the morning but good visibility in the afternoon

Alerts

- All alerts (except of the runway crossing alerts) are switched on the regular CWP for one week now
- Ciurrent procedures require that the alerts be switched off when the visibility drops below 3000m
- Long-term alert performance questionnaire that was distributed to the TEC CWP is not regarded by the controllers
  - No audible alert and TEC use E2000 as primary display
  - Red alerts are very rare and if they are unwanted they are not recognised by the TEC
  - TEC does not take the time the note the alert performance
- Audible alert has not been installed because it is very distracting due to its high volume and permanent signal (peep). As yet, the controllers have not specified what is required.

EMMA System

- The EMMA system was unreliable during the this day due to a hardware fault which was corrected.

Flight Tests

- No flight test today, because the EMMA system is needed to test the runway crossing alerts that are not part of the commercial A-SMGCS
- The day after planned DEP-DEP; DEP-APP; and DEP-CROSSING conflict shall be tested with vehicles and normal traffic to save costs and time.

DMAN

- DMAN was not running in the morning but has been rebooted from Braunschweig remotely
- Flight plans were there and planning and real traffic matched together (passive mode).

17th of January 2006

Weather conditions

- Snow but
- runways and taxiways are cleared from snow
- Good visibility the whole day

Alerts

- Audible alerts have been tested to install them on the Tower, but were estimated as too loud and too permanent until the conflict is solved – this is not acceptable to the controller because it could distract the communication of other CWP
- However one single „peep“ would be acceptable and even wanted by the controllers, however this could not be implemented during the field trials.

EMMA System

- EMMA System is running again and will additionally be installed at the TEC CWP for the time of the flight tests (this is needed because the commercial A-SMGCS does not include runway crossing alerts)

Flight Tests
- Crossing runway alerts case studies were performed from 1200 to 1230 with an EMMA vehicle and normal traffic (cf. Test Observer sheet 4.2.3)
- DEP-DEP and DEP-CROSSING have been tested
- DEP-APP could not be tested because no regular arrival was expected in the near future but will be done the day after.

DMAN
- DMAN was running but not continuously
- DEP RWY13 is not indicated with DMAN because the DMAN is only outlined for the more usual runway configuration with the beginning - columns are occupied by RWY24 and RWY31

18th of January 2006
Weather conditions
- 8000m visibility
- RWY24 and RWY31 in use

EMMA System
- Runs perfectly
- Alitalia did not switch on the transponder, which seems to be quite normal the ATCOs said
- Controllers said “Time to threshold” window shall be updated to “time and more” instead of the current “time and less”
- Alert and Visibility settings shall be permanently displayed

Flight Tests - Case Studies Crossing runway alerts
- DEP31 – DEP24, DEP31 – APP24, DEP31 – Crossing RWY31 via Foxtrot have been tested (see observer sheet and pictures)
- DEP31 were simulated by a test vehicle “EMMA”
- APP24 and Crossing were performed by normal traffic
- EMMA A-SMGCS was switched on at the TPC CWP – other CWP were commercial A-SMGCS
- 5 DEP-DEP; 5 DEP-APP, and one crossing were tested within 45 min
- Nearly all alerts worked fine

DMAN
- Running continuously

23rd of January 2006
Weather conditions
- 8000m visibility
- RWY06 and RWY31/13 in use
- Wind calm
- -16°C
- Snow

EMMA System

- False Targets
  - There was snow and operations were interrupted by snow-clearing
  - Snow and ice has to be cleared from the movement area otherwise it will cause unwanted radar targets
- Missing departure flight plans
  - A controller reported that he has the feeling that when aircraft go off-block very early or very late compared to its EOBT the flight plan is missing in the departure list on the A-SMGCS surveillance display, (the reason for this needs further investigation)
    - Actual OBT very far away from EOBT happen very often in winter time when de-icing procedures have to be used

Flight Tests - Case Studies Crossing runway alerts

- Flight tests with two CAA test aircraft CBA40 (BE40) and CBA41 (L410) concentrated on Approach – Approach conflicts exclusively, because this conflict could not be tested with test cars the week before
- The alert parameters have been changed by ANS_CR so that stage1 alert arises appr. 45 seconds before threshold
- Alerts worked fine but probably still to early – alert parameters were tuned again for the next day

DMAN

- No activity (no flight plans are indicated) because DMAN is only tuned for RWY 24 and RWY31

24th of January 2006

Weather conditions

- 8000m visibility, no clouds
- RWY24 and RWY31/13 in use
- Wind calm
- -10°C
- Snow

EMMA System

- Worked fine again
- MT (ANS_CR) proposed to switch off primary targets when LVP is in force:
  - This would solve the problems with false targets and false alerts due to snow and heavy rain
  - During LVP, all movements (aircraft and vehicles) must be equipped with Mode-S
  - Snow Ploughs in convoy where mostly only one vehicle is equipped are not used during LVP or the runway will be closed
  - AG (PAS) said that this is technically possible to arrange but he warned of non-equipped targets that cannot then be seen anymore
  - JJ (DLR) asked if the controller could be given the possibility to delete false targets on the display (when s/he has verified 100% that the target is false)
  - No decision on this

Flight Tests - Case Studies “Crossing runway conflicts”

- With new alert algorithm settings, the information and alerts popped up later
- The decision on which settings are better could not be taken but must be discussed later
- Generally, all alerts worked fine today

- After the case studies ANS_CR decided that they want to get the information earlier

DMAN

- Worked fine

25th of January 2006

Weather conditions

- 7000m visibility
- RWY24 and RWY31/13 in use
- Wind calm
- -10°C
- Snow

EMMA System

- Worked fine again
- When LVP, then:
  - Stop bars are switched on
  - Intersections or stop bars are used as visual reference points for pilots to hold when needed
  - The controller has never experienced that pilots have not been able to see each other
  - The controller estimates: to follow an aircraft by looking out of the cockpit should be possible down to 100m visibility but those sight conditions are very unlikely

Flight Tests - Case Studies "Crossing runway conflicts"

- Unwanted DEP-DEP alerts
  - DEP13 – DEP24 alerts have been observed, which are absolutely unwanted because aircraft are diverging and would never meet with those speed vectors
- Results of the day were fine but probably stage 2 alert was a bit late sometimes, but this has to be discussed with other operational people
- Single Arrival alerts
  - They are currently set with 30 sec for stage 1 and 15 sec for stage 2
  - But, these settings are probably too low because T2 = 15 sec is sometimes below the decision height
  - A better setting could be stage 1 alert (T1) = 40 sec and stage 2 alert (T2) = 20 sec

DMAN

- Worked fine

5 Conclusions

5.1 Prague V&V Approach

The A-SMGCS V&V activities with Prague Ruzyne Airport were done on two validation platforms:

- Real Time Simulation (RTS) and
- On-site at the Prague Ruzyne Airport.

Three levels of V&V activities have been performed on both platforms:

- Technical Tests (Verification),
- Operational Feasibility (Validation), and
- Operational Improvements (Validation).

Different objectives were aimed for with the different test platforms and levels of testing. The technical tests checked whether the installed A-SMGCS in the simulation or in the Tower environment fulfilled all technical requirements to enable the operational use of the system and to perform the validation activities. The technical systems answered the question: “Did we set up the system right?”.

RTS and *On-site trials* focussed on validation activities but with two different levels of testing. Real Time simulations usually offer a good opportunity to measure operational improvements in terms of objective traffic data (e.g. taxi times, R/T load, etc.). They were also used to investigate safety critical situations like low visibility conditions or conflict situations without any danger.
On-site trials were mainly needed to test the system in the real environment in terms of its technical performance and of its operational feasibility. The controllers who worked with the A-SMGCS fully operational (within all visibility conditions) were asked if they accept the A-SMGCS design, performance, and the new operational procedures. All platforms and levels of testing were needed to fully validate the A-SMGCS.

5.2 Prague V&V Results

The A-SMGCS, which was installed at Prague Ruzyne Airport, has been validated. All technical and operational results affirm the overall main question: “Did we build the right system?”.

All main technical and operational requirements could be verified (cf. 2.4 and [11]). For this purpose, technical short- and long-term measurements have been conducted. With some requirements the system performance could not fully meet the standards (e.g. “Op_Perf-01-Probability of Detection” should be 99,9% but only 99,65% was measured) but the controllers’ acceptance of this slightly lower performance showed that even a lower PID could be valid to work with it safely and efficiently.

For the long-term system performance measurements, the MOGADOR tool was used. MOGADOR is a tool, developed in EMMA, that analyses fully automatically specific performance parameters from a long-term recorded data pool of the regular airport traffic. This tool revealed interesting results that can also be used to tune and adapt the A-SMGCS to meet the operational needs. However, the Prague long-term results, analysed with MOGADOR, still lack maturity because the time was not sufficient to fully adapt the MOGADOR algorithm to the specific Prague airport characteristics, which is always needed to measure the real system performance automatically.

The operational on-site trials (field tests) revealed that the controllers, who have worked with the A-SMGCS fully operationally for 7 months now, 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. The statements mainly refer to the surveillance service of the A-SMGCS, because the ANS_CR controllers have not used the full scope of the monitoring and alerting function yet but only the "stop bar crossing" alerts as a first step. However, flight tests, which were used to evoke additional conflict situations at crossing runways, showed that also the performance of other monitoring alerts was accepted by the controllers.

To fully validate a system it must also show its operational improvements. This was mainly done in real time simulations because RTSs can provide real experimental conditions. The most important result of the RTS was that **A-SMGCS is able to reduce the average taxi time**. In both simulation phases, the average taxi time was reduced by 13,6% and 7,1% respectively. Both results are highly significant with 968 total movements.

Furthermore, **A-SMGCS reduces the load of the R/T communication**. With RTS1 a reduction of 16,0% and with RTS2 a reduction of 11,1% was measured, whereas only the RTS1 results showed statistical significance.

A further operational improvement can be assumed with the **"controller's reaction time in case of a conflict situation": 5,3 seconds instead of 6,0 seconds** without A-SMGCS showed an interesting trend but became not significant. However, with a bigger sample size it can be assumed that this small effect could also become significant.

These objective operational improvements, which were measured on the real-time simulation test platform, could also be confirmed with controllers' subjective statements in the field. Controllers 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. The following main results were gained:

- "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."

These examples, which were all positively answered by the controllers, further support the hypothesis that A-SMGCS provides significant operational improvements that will result in operational benefits for all stakeholders of an A-SMGCS.

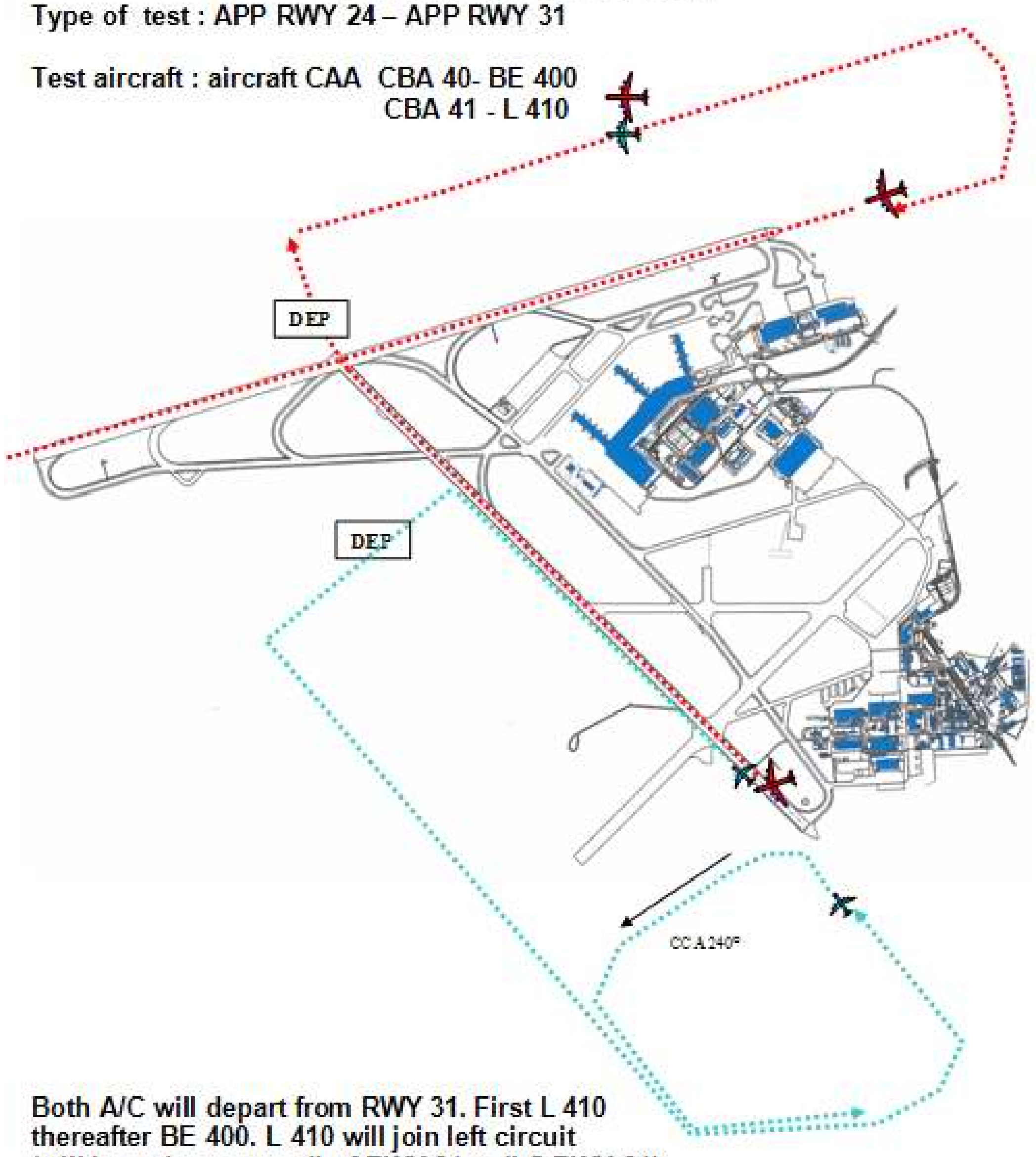
6 Annex

6.1 Flight Tests Scenarios

TEST 1 dep 31
EMMA ASMGCS

Type of test : APP RWY 24 – APP RWY 31

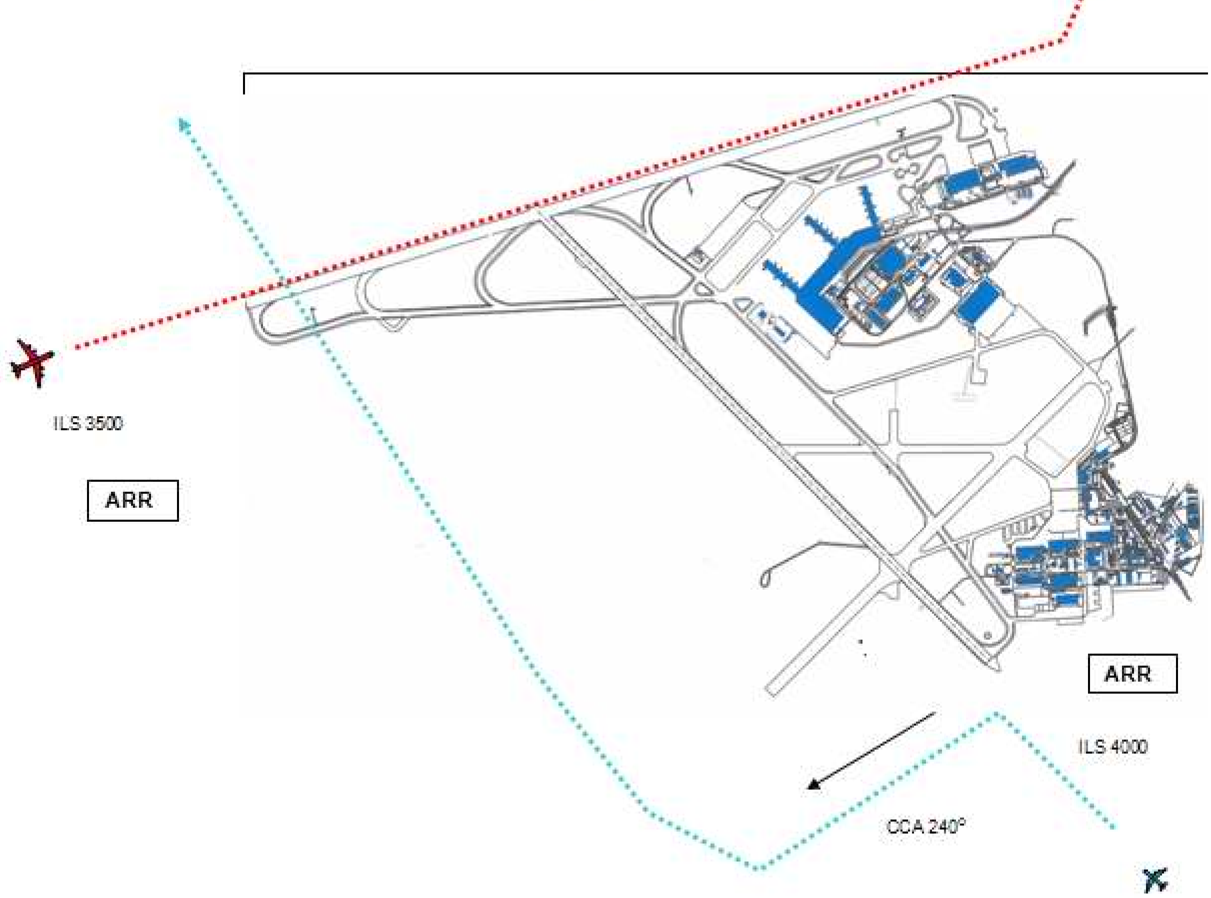
Test aircraft : aircraft CAA CBA 40- BE 400
CBA 41 - L 410



Both A/C will depart from RWY 31. First L 410 thereafter BE 400. L 410 will join left circuit (will be radar vectored) of RWY 31 to ILS RWY 31). BE 400 will join rigt circuit (will be radar vectored) of RWY 24 to ILS RWY 24. The both aircraft should be established on final track at same distance front of THR. When alert appears (not later then over THR RWY 31), L 410 will get instruction to turn to the left (ca. heading 240°) and change to DIR and will be radar vectored to ILS RWY 31. BE 400 will make go around over RWY 24 and will be radar vectored to ILS RWY 06.

TEST 2
EMMA ASMGCS

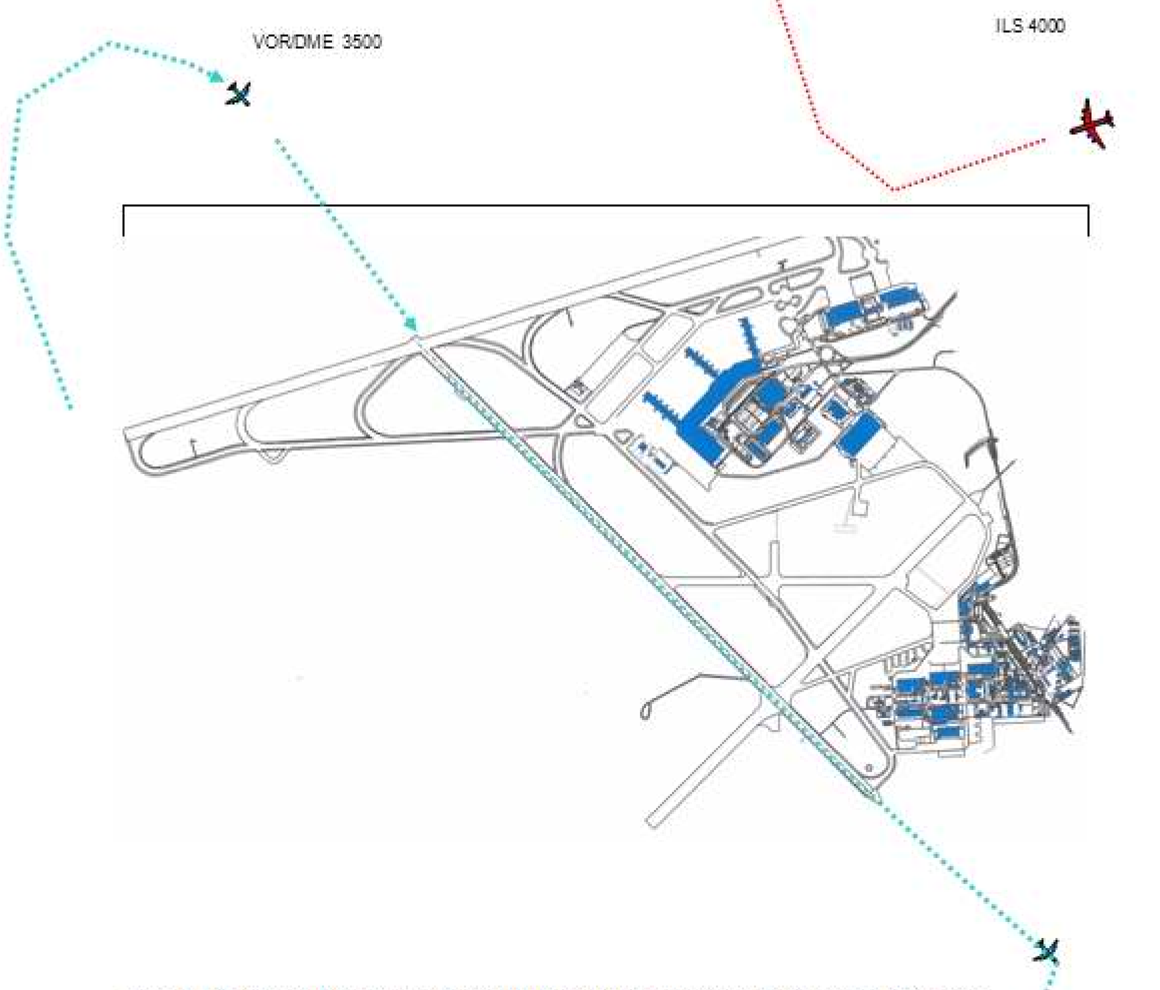
Type of test : APP RWY 06 – APP RWY 31
Test aircraft : aircraft CAA CBA 40 - BE 400
CBA 41 - L 410



The both aircraft should be established on final track at same distance front of THR. When alert appears (not later then over THR RWY 31), L 410 will get instruction to turn to the left (ca heading 240°) and change to DIR and will be radar vectored to VOR/DME RWY 13. BE 400 will make go around over RWY 06 and will be radar vectored to ILS RWY 24.

TEST 3
EMMA ASMGCS

Type of test : ARR RWY 24 – ARR RWY 13
Test aircraft : aircraft CAA CBA 40- BE 400
CBA 41 - L 410



The both aircraft should be established on final track at same distance front of THR. When alert appears (not later then over THR RWY 24), BE 400 will get instruction to turn to the right (ca heading 360°) and change to DIR and will be radar vectored to ILS RWY 24. L 410 will make go around over RWY 13 and will be radar vectored to ILS RWY 31.

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6.3 Abbreviations

Acronym	Meaning
ADS-B	Automatic Dependent Surveillance - Broadcast
AGL	Aerodrome Ground Lighting
ANS CR	Air Navigation Services of the Czech Republic
ARP	Aerodrome Reference Point
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASR	Airport Surveillance Radar
ASTERIX	All-Purpose Structured Eurocontrol Surveillance Information Exchange
ATC	Air Traffic Control
ATM	Air Traffic Management
AUX	Auxiliary Mass Storage Unit
BITE	Built-In Test Equipment
BRM	Bearing and Range Marker
CDD	Clearance Delivery Dispatch
COTS	Commercial-Off-The-Shelf
CWP	Controller Working Position
df	Degrees of freedom
DSNA	Direction des Services de la Navigation Aérienne
EC	European Commission
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESUP	Eurocat Support system
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
F	F value in the F statistics
FAT	Factory Acceptance Test
FDPS	Flight Data Processing System
FHA	Functional Hazard Analysis
GEC	Ground Executive Controller
GFS	Gap Filler System
GSR	Ground System Requirements
HMI	Human-Machine Interaction
HW	Hardware
ICAO	International Civil Aviation Organisation
ID	Identifier
IP	Internet Protocol
KVM	Keyboard/Video/Mouse
LAN	Local Area Network
LAT	Latitude
LCD	Liquid Crystal Display
LON	Longitude
LVP	Low Visibility Procedures
M	Mean
MET	Meteorological
MLAT	Multi-Lateration
MVP	Machine Vision Processor

Acronym	Meaning
NTP	Network Time Protocol
p	p-value (error probability that the measured mean belongs to the H0 hypothesis)
PAS	Park Air Systems AS
PDAS	Probability of Detecting an Alert Situation
PFD	Probability of False Detection
PRG	Prague
PTL	Predicted Track Line
PU	Processing Unit
RANC	Radar Analyser and Compressor
RCMS	Remote Control and Monitoring System
RDPS	Radar Data Processing System
RPA	Reported Position Accuracy
RPS	Recording and Playback System
RS	Recommended Standard
RVA	Reported Velocity Accuracy
RWY	Runway
SAT	Site Acceptance Test
SD	Standard Deviation
SDF	Sensor Data Fusion
SDS	Surveillance Data Server
SID	Standard Instrument Departure
SMR	Surface Movement Radar
SP	Sub-Project
SQB	Squitter Beacon
SSA	System Safety Assessment
STAR	Standard Terminal Arrival Route
SW	Software
TCP	Transport Control Protocol
TEC	Tower Executive Controller
TECAMS	Technical Control and Monitoring System
TPC	Tower Planning Controller
TRUR	Target Report Update Rate
TWY	Taxiway
V&V	Verification and Validation
VSDF	Video Sensor Data Fusion
WGS	World Geodetic System
WP	Work-Package

6.4 List of Figures

6.5 List of Tables

END OF DOCUMENT