Nationaal Lucht- en Ruimtevaartlaboratorium

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A Full Visual A-SMGCS Simulation Platform

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Summary

In this paper, we present the construction and evaluation of a real-time full vision Advanced Surface Movement Guidance and Control System (A-SMGCS) simulation platform for controllers and pilots, including several advanced sensor simulators and a surveillance function. The project was the first to demonstrate and use a full A-SMGCS platform for evaluation of A-SMGCS operational concepts and procedures.

Essential bases for the simulator were the sensor simulation and surveillance functions. Simulated ASDE, a Mode-S multi-lateration system, and a D-GPS formed the sensors that provided input for the surveillance function, which had the possibility to specify a track-loss and track-swap ratio. Output of the surveillance function was used by several A-SMGCS processes and displayed at the controller working position on a plan view display and electronic strip panel.

The project demonstrated that improved situational awareness through the use of advanced sensor and surveillance technology aided the controllers in carrying out their task. We conducted several tests where different sensor qualities were available to the controller and where labelled surveillance was made available for the full 100% accuracy or with a predefined track-loss rate. Several weeks of trials with operational controllers and pilots were carried out. We showed the benefit of improved technology for ground sensors to aid the controller and to provide the necessary information to other A-SMGCS processes, like runway incursion alert and planning.

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Abstract

In this paper, we will present the construction and evaluation of a real-time full vision Advanced Surface Movement Guidance and Control System (A-SMGCS) simulation platform for controllers and pilots, including several advanced sensor simulators and a surveillance function. The project was the first to demonstrate and use a full A-SMGCS platform for evaluation of A-SMGCS operational concepts and procedures.

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1 Introduction

Currently, operational procedures on the surface of an aerodrome depend on air traffic controllers, pilots, and vehicle drivers using visual observation of the location of aircraft and vehicles in order to estimate their respective relative positions and risk of collision. During periods of low visibility, controllers must rely on the pilot's Radio/Telephony (RT) reports and surface movement radar to monitor separation and to identify conflicts. In these conditions, pilots, and vehicle drivers find that their ability to operate in the "see and be seen" mode is severely impaired.

It is expected that A-SMGCS will help to enhance airport efficiency and capacity in low visibility, while at the same time maintaining the current safety level. A-SMGCS cannot be introduced without extensive off-line trails and there is a fast growing need in Europe for a simulation environment capable of testing, evaluating, and demonstrating in a comprehensive environment all the advantages of newly developed A-SMGCS concepts. Such a facility allows pilots and controllers to evaluate new A-SMGCS concepts and procedures. In addition, airport authorities are able to evaluate trial A-SMGCS equipment and aviation authorities are able to safely evaluate new A-SMGCS procedures before enforcing them operationally.

Many A-SMGCS projects have been set up in the last few years, leading to first operational implementation of surveillance functions and runway incursion alert functions at airports at this moment. Most projects focussed on one particular aspect of A-SMGCS, either on the conceptual level or to study one proposed function. Some small simulators have been constructed without connection to an outside visual simulator. Until now, no projects or programs have been set up to create a full A-SMGCS simulator with both controllers and pilots in-the-loop that also provide outside visuals for the operators.

SAMS [1] [2] and ATOPS [3] [4] are two projects, co-funded by the European Commission to improve the total ground movement at airports. Participants in the project are research institutes, industry, and air traffic control agencies. The SAMS (SMGCS Airport Movement Simulator) project was dedicated to the design and development of a platform for real-time, man-in-the-loop

A-SMGCS simulations, including outside visuals for controllers and pilots. ATOPS (A-SMGCS Testing of Operational Procedures by Simulation) defined and evaluated relevant A-SMGCS concepts and procedures for this simulator. The joint result is a simulator for the airport ground environment with a capability of testing, evaluating, and demonstrating new support functions, tools, and/or new A-SMGCS procedures safely and in all weather conditions.

The simulation platform described in this paper consists of a control tower, including an outside view projection system, located in Braunschweig (Germany), see figure 1, a Boeing 747 cockpit, located in Bedford (United Kingdom), see figure 2, and a newly built A-SMGCS simulator located in Amsterdam (The Netherlands). These geographically distant locations have been coupled in real-time. The projects simulate outside visuals and procedures of Amsterdam Airport Schiphol and London Heathrow.

Figure 1. Impression of the A-SMGCS control tower with outside visual (from DLR web site).

Figure 2. LATCH Boeing 747 cockpit.

2 Architecture

Within the frame of the projects, based on current insight in the field [5] [6], A-SMGCS is divided in the following functional areas:

- *Surveillance.* A function of the system that provides identification and accurate positional information on aircraft, vehicles, and unauthorised targets within the required area.
- *Control.* Application of measures to prevent collisions, runway incursions, and to ensure safe, efficient, and expeditious movement.
- *Routing.* The planning and assignment of a route to individual aircraft and vehicles to provide safe, efficient, and expeditious movement from its current position to its intended position.
- *Guidance.* Facilities, information, and advice, necessary to provide continuous, unambiguous, and reliable information to pilots of aircraft and drivers of vehicles to keep their aircraft or vehicles on the surfaces and assigned routes intended for their use.

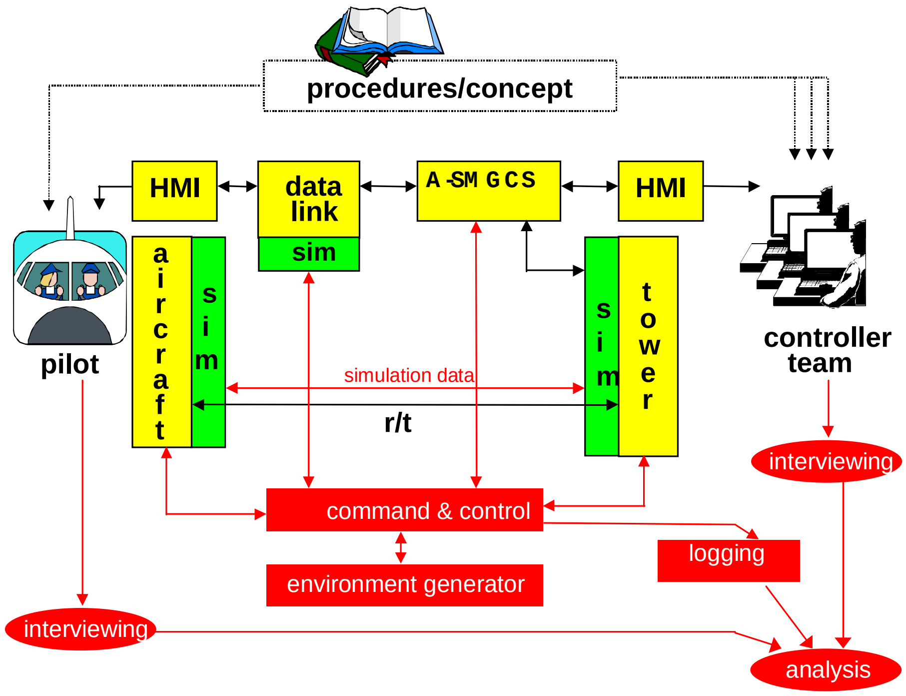

Figure 3. Global architecture of the A-SMGCS simulation environment.

Figure 3 gives and overview of the architecture of the SAMS simulation environment. Each A-SMGCS item has been substituted with a simulator, which in this way consists of the following major components:

- The LATCH cockpit simulator. This is a generic Boeing 747 with two pilot positions, representative cockpit controls and instrumentation, and simulated out-of-cockpit visuals. For the purpose of the project, it was equipped with a dedicated pilot HMI to relay A-SMGCS messages from the A-SMGCS simulator to the cockpit and vice versa.
- The ATS tower simulator. This is a 300° tower visual simulator that is in use for vision based air traffic control in the vicinity of airports. Simulated aircraft are controlled by pseudo pilots in a separate control room. Pseudo pilots communicate with the controllers via a simulated radio transmission line. An HMI for the controller was designed to enable interaction with the A-SMGCS simulator.
- The A-SMGCS simulator. This consisted of a network of seven work stations, connected through CORBA middleware. Apart from A-SMGCS functions, a number of support functions for aircraft performance models, topology models, logging facilities, etc. was available.

- A datalink facility, between the A-SMGCS simulator and LATCH. For this, a dedicated ISDN line was available. Communication between the simulators was established through the Distributed Interactive Simulation (DIS) protocol.
- A voice channel, between LATCH and ATS. The available communication facilities in both the cockpit and the tower simulator were relayed via a normal telephone line.
- Supplemental software components and procedures to support the simulations such as an environment generator, simulation command and control, logging, and analysis.

While LATCH and ATS are existing simulators, construction of the A-SMGCS simulator has been one of the activities in the project. Gaining experience with multi-site simulations through connecting different simulators was part of the objectives of the project.

In figure 3, displayed in yellow are "real" facilities, i.e. a control tower, a flight simulator, human machine interfaces for the controllers and pilots, A-SMGCS functions, and a datalink facility. For ATS and LATCH and for the datalink, additional hard- and software is required to enable their simulation function, e.g. aircraft performance models. A green box attached to the facility indicates these functions. The functions displayed in red show additional facilities necessary to the A-SMGCS platform to connect the simulators and to enable evaluations with the platform. These would not be implemented in a real A-SMGCS implementation. Finally, controllers, pilots, and new procedures and concepts are needed to enable simulations and evaluations. With the definition of the functions, a standard for a software architecture emerges, where each of the functions consist of a partial implementation of an A-SMGCS component.

With the proposed architecture, all aspects of A-SMGCS are covered and a first step in the standardisation of software functions and interfaces has been provided. The A-SGMCS simulation platform was capable of demonstrating functions for labelled surveillance, electronic flight strips, runway incursion alert, taxiway routing, datalink, and a dedicated A-SMGCS Human Machine Interface (HMI).

In the remainder of this paper, we will focus on the sensors and surveillance functions that were implemented, integrated, and evaluated in the aforementioned projects.

3 The surveillance function and labelled display

Basis for the surveillance function formed a set of simulated sensor functions. The ground situation was built up from three simulated sensors, an ASDE, a Mode-S multi-lateration system, and a D-GPS. To simulate uncertainty, each sensor had the possibility to specify a track-loss and track-swap ratio. All sensors took into account the airport topological information and were designed to be configurable.

The surveillance function was composed of a multi-sensor data fusion and labelling system responsible for the elaboration of the ground situation in terms of kinematic information (position, velocity, heading) and mobile (aircraft and vehicle) identification. The output of the surveillance function was filtered through the removal of non-moving (parked) tracks so as to avoid clutter and remove non-essential traffic. The resulting reduced traffic situation was presented to the controller HMI.

Labelling was done, either automatically by associating the elements received from the sensor simulator and the elements received from the flight plan, or manually by controller assignment of identification to tracks from the controller HMI.

Figure 4 shows the controller HMI. Together with an electronic strip panel, this HMI supplied the controller with information regarding the current and future traffic situation. Major part of the display is taken by the horizontal situation display. The display was configurable through the standard windows zoom in/out and re-centre options. Besides that, the controller could configure the display according to his own preferred look-and-feel by filtering specific parts and by choosing his own preferred colour scheme and font sizes. Pull down menus as indicated at the top of the figure provided many options.

To ease finding specific tracks and relations between the horizontal situation display and the electronic strip panel, inbound traffic was displayed in yellow, while outbound was in blue, conform the current strip coding. Controllers were able to access more information on tracks through moving the mouse over the accompanying label, through clicking on the label, or through selecting the option "full labels" from a menu. Label de-conflicting was performed automatically.

The HMI was enriched with traffic information from arrival traffic with a distance-to-touchdown indicator at the bottom of the display.

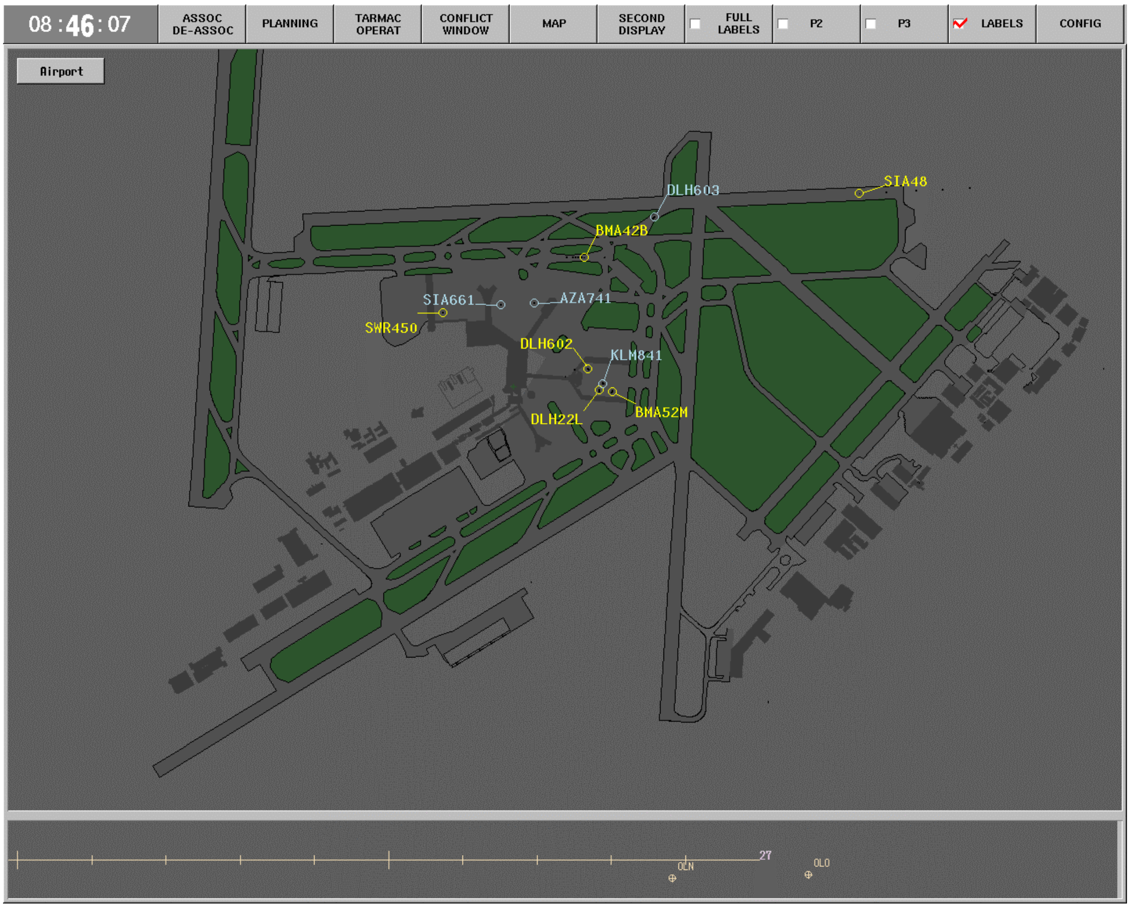

Figure 4. Controller HMI used in the SAMS and ATOPS trials.

4 Research questions

For the evaluations, a set of research questions was defined. These questions formed the basis for a quantitative and qualitative evaluation of A-SMGCS procedures. The research questions for the surveillance function concentrated on the impact of additional information on the HMI in the form of labels. The hypothesis was that the additional information contained in the labels would enhance the situational awareness of the controllers, thus enhancing the capacity and efficiency of the traffic flows at the airport. This should especially be true for adverse visual conditions.

The questions concerned:

- Are controllers able to work with the labelled situation display?
- Do controllers feel that procedures with respect to identification of traffic on the airport has operational significance?
- Can controllers dispense with the paper flight strips?
- Is there an indication of an increase in capacity or reduction of controller workload during low visibility conditions due to the use of a labelled display?
- What kind of system deficiencies can the controller accept with respect to label swap, label drop, loss of track, and positional inaccuracy?

The definition and selection of operational procedures was broken down into three sub-tasks, namely airport ATC (Air Traffic Control) consultations, selection of procedures, and procedure descriptions. The airport ATC consultations involved four major European airports (London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, and Frankfurt). Through the use of comprehensive questionnaires and interviews, the ATC authorities provided information on their airport's present SMGCS, future planned A-SMGCS, perceived business benefits of A-SMGCS, and possible operational procedure topics for A-SMGCS. The interview subjects agreed with a set of 'basic' or 'core' procedures for A-SMGCS that were put forward by the ATOPS project team. The 'core' procedures were defined as enablers that give controllers the basic skills, initially to exploit enhanced surveillance and eventually to use other advanced tools. Examples of the 'core' procedures are "Identification of SMR (Surface Movement Radar) labelled aircraft", "Conflict detection and alert by a controller", "Tactical ground movement control instructions", "Line up after an arrival or departure", and "Cross the runway after an arrival or departure".

Advanced procedure topics that were also suggested encompassed the automatic routing/planning (taxi and departure), guidance (automated switching of lighting and signage, free taxi), and the control functions for runway and taxiway conflict alert, including incident management and missed approach management.

5 Experiment set-up

Following the construction of the A-SMGCS simulation platform, new operational procedures were identified for evaluation. The focus of these procedures has been put on enhancement of capacity and efficiency of airport ground movements in a safe manner. The controllers have been exposed to traffic scenarios with low, medium, and high intensities of traffic. Each of the scenarios was used in good, medium, and low visibility conditions. In some of the runs, the controllers were asked to perform their task as they would in the normal control tower; in some runs, they were asked to intentionally create "problem situations" to see how the A-SMGCS functions would respond.

Two weeks of *technical* evaluations were performed, one week for the Schiphol situation and one week for Heathrow. These weeks were used for training of controllers and pilot, for technical testing of the platform, and for baseline simulations. To be able to compare the results of the simulations with the advanced platform, baseline simulations have been performed to assess the quality of the platform. The baseline validations succeeded in providing a controller workload that is comparable to present day operations. The major factor that initially restricted a heavy workload for the controller was not technical, but the workload of the pseudo pilots. This could easily by extended with more pseudo pilots during the simulations, where for peak hours of simulations up to six pseudo pilots participated simultaneously.

The *operational* evaluations ran over a five week period. The first two weeks were set up of Schiphol simulations using Dutch controllers and the latter three weeks for Heathrow simulations using Heathrow controllers. The controllers were (former) operational controllers at the airports mentioned. Each week started with a short training and familiarisation session, followed by the real evaluations. Each simulation day started with a briefing for the day. Typical simulation 'slots' ran for around an hour followed by a thorough de-briefing session. Each simulation day provided for four to five evaluation runs.

During each evaluation, an external observer was present. This observer had been involved in the preparation of scenarios and as such was well informed on the development. The use of simulators provided a good possibility to log all information flows between the simulators and between the different functions of the simulators. A video camera registered all controller actions. During the de-briefings, the controllers were asked to fill out questionnaires and had thorough discussions with the observer, possibly using the video recordings made during the session.

6 Evaluations

During and after each simulation run, observers checked whether aircraft were delayed while taxiing on the airport and determined whether those situations when delays occurred where any different than what would have occurred in real-life. No discrepancies between the simulation and real airport operations were identified in this aspect of the trial scenarios [7].

The controllers were able to use the labelled HMI to guide the traffic on the airport without any significant changes to the usual operations of the airport. Even in the low visibility scenarios, the controllers were able to cope with high traffic densities.

Intentional data errors were introduced in the system, leading to wrong combinations of flight strip, label on the horizontal situation display, and the R/T identification used by the pilot. Mixing up types of aircraft, leading to a mismatch on the visual presentation of the aircraft on the outside view and the data on the flight strip and the labelled display, produced a similar scenario. In the majority of the cases, after getting acquainted to using the labelled display, the controllers had no trouble identifying the various data errors introduced by the test team.

However, in a limited number of cases, the mismatch in the type of aircraft was missed by the controller, especially when the flight strip and the horizontal situation display showed the same (wrong) information. This mismatch has been blamed on the low resolution of the simulated outside visual (low compared to what the human eye is capable of), the fact that the type of aircraft was not shown in the default label on the horizontal situation display, and to the controller not checking the flight strip when using the labelled display extensively. It is likely that in a real tower, the controllers eyes would have picked up the details of aircraft types and liveries that were missed in the simulator.

It can be concluded that the labelled situation display is extremely helpful to controllers, because it helps them to identify and guide traffic on the airport surface especially during low visibility conditions. Subjective observations indicate that controllers workload decreased. This was apparent in the observed reduction in R/T communication and a calmer atmosphere in the tower. It would seem as though the controllers using the HMI needed fewer checks to form a mental picture of the traffic situation on the airport and to keep this picture updated.

Once the controllers started to rely on the surveillance function provided by the simulation platform, advanced functions for runway incursion alerting, planning, and guidance were introduced. The surveillance function was considered a prerequisite for the introduction of runway incursion alert and planning. Reliable surveillance will be needed as a start for more enhanced functions.

7 Conclusion

The SAMS and ATOPS projects have proven the feasibility of an A-SMGCS multi-site real-time man-in-the-loop platform. The projects were the first to couple a manned outside visual flight simulator to a tower visual simulator and an A-SMGCS. Three geographically distant locations were coupled in (almost) real-time. The project provided the possibility of evaluating new A-SMGCS operational concepts and procedures in a simulation environment with pilots and controllers in-the-loop.

Candidate operational procedures for simulation and conducting simulation tests of ‘core’ procedures using the SAMS platform were identified. A dialogue between researchers, technology providers, and ‘end-users’ such as controllers necessary for providing a practicable A-SMGCS was achieved. The project was partially successful in preparing ‘advanced’ operational procedures for A-SMGCS functions. Due to technical difficulties during the simulation, it was not possible to record performance data.

A key conclusion that can be made is that the implementation of a labelled A-SMCS display in a control tower will be beneficial in terms of providing the controllers with a better understanding of the traffic situation on the airport surface. This would apply particularly in medium and low visibility conditions. If the labelled A-SMGCS display will improve the controllers' situational awareness (as the simulations indicate), it is likely to increase the efficiency and number of movements handled on the airport surface in medium and low visibility conditions. Another potential benefit of the labelled A-SMGCS display is that it can provide the controllers with a clear 'picture' of the cul-de-sacs, apron areas, or blind spots on the airport.

The procedure with respect to identification of traffic as drafted in the project is a good start to the task of developing new procedures for A-SMGCS. The controllers were able to apply it to the situations they were exposed to with success. Any failure in identifying traffic or spotting system errors (e.g. wrong labels) were not due to the procedures themselves, but were caused by limitations of the simulation and lack of proper knowledge of the simulation platform when the procedures were designed. A good example of this is the absence of the type of aircraft in the default label on the horizontal situation display. Procedures and the systems used by controllers should be designed in close co-operation in order to prevent things like these from happening in actual A-SMGCS implementation projects.

Controllers readily accepted the labelled surveillance function, after which the other advanced functions for runway incursion alerting, taxiway and runway planning, and guidance were introduced one-by-one. Feedback on these other functions differs in detail because of the level of evaluation, but it can be concluded from the observations that the controller workload decreased. The evaluation provided further significant feedback on the usability of the A-SMGCS HMI, the proposed functions, and on the areas that need further development, both in terms of A-SMGCS sub-systems and also for operational procedures.

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