SAMS

Final Report for Publication (Deliverable D5.5)

DOCUMENT ID CARD

Title	Final Report for Publication
SAMS document number :	C/NLR/00/006
Author	Henk Hesselink, Frédéric Reich, John Snape, Frans van Schaik, Thierry Jourdan, Jelle Beetstra, Arjan Rodenburg, Ralph Pantelides, Mark Green, Angeles Varona
Subject	SAMS final report with public available information
Related task	WP5000
Date of first delivery	07/04/2000
Date of last revision	11/07/2000
Revision number	1.0

Final Report for Publication

SAMS

AI-97-SC.2097

Project Coordinator: THOMSON/DETEXIS

Partners:

- NLR
- THOMSON/ISR
- DERA
- NATS
- INTA
- SKYSOFT
- SOFREAVIA
- AENA
- AEROSPATIALE

Project Duration: 1 January 1998 to 11 July 2000

Date: 11 July 2000

PROJECT FUNDED BY THE EUROPEAN
COMMISSION UNDER THE TRANSPORT
RTD PROGRAMME OF THE
4th FRAMEWORK PROGRAMME

.

DOCUMENT DESCRIPTION

RELATED TASK : WP5000	TITLE : Final Report for Publication	SAMS REFERENCE : C/NLR/00/006

KEY WORDS	SAMS, DG-TREN, A-SMGCS, A-SMGCS simulation, flight simulation, airport tower simulation, real-time simulation, distributed simulation, A-SMGCS operational concept, A-SMGCS architecture design, A-SMGCS implementation, A-SMGCS HMI, surveillance, control, runway incursion, taxiway collision monitoring, runway planning, taxiway planning, data link, guidance, CORBA, DIS.
AUTHOR'S SUMMARY	The SAMS project, sponsored by the European Commission (DG-TREN) aims at the development and evaluation of a A-SMGCS real-time, men in the loop simulation platform. The demonstration of this platform involved professional pilots and controllers using scenary databases of Heathrow and Schiphol Airports. Within this context, the goal of the SAMS project was to design and develop a real-time, man-in-the-loop platform capable of testing and demonstrating new support tools and new A-SMGCS procedures in all weather conditions. This platform offers a highly realistic substitution of the outside views and of the working environment. Among other things, a pilot working environment (LATCH, B747 cockpit), a controller working environment and an outside view projection system of a Control Tower (ATS) are integrated and connected to the core A-SMGCS simulator. The three simulators were located at three geographically distributed sites. LATCH was located at DERA in Bedford (UK), ATS at DLR in Braunschweig (D), and the A-SMGCS simulator was based at NLR in Amsterdam (NL). While LATCH and ATS are existing simulators, construction of the A-SMGCS simulator was one activity in the project. Gaining experiences with multi-site simulations through connecting different simulators was part of the objectives of the project.

ACTION	NAME	DATE	SIGNATURE
PREPARED BY	H.H. Hesselink, F. Reich, J. Snape F.J. van Schaik, T. Jourdan, J. Beetstra, A. Rodenburg, R. Pantelides, M.P. Green, A. Varona	11/07/2000	
APPROVED BY		11/07/2000	

REVISION RECORD SHEET

INDEX	DATE	DOCUMENT CHANGE	NAME
1.0	11/07/2000	Provision of document to EC	H.H. Hesselink

TABLE OF CONTENTS

1. INTRODUCTION 7

1.1. SCOPE 7
1.2. BACKGROUND AND RECAP OF THE SAMS OBJECTIVES 7
1.3. SAMS PARTNERSHIP 8

2. PROJECT OBJECTIVES 9

2.1. A-SMGCS CONTEXT 9
2.2. ENHANCEMENTS STUDIED IN THE SAMS PROJECT 10
2.3. MEANS USED TO ACHIEVE THE OBJECTIVES 10
2.4. EARLY ASSESSMENT OF THE SAMS ACHIEVEMENTS 11

3. SCIENTIFIC AND TECHNICAL DESCRIPTION OF THE PROJECT 12

3.1. WP1000: OPERATIONAL CONCEPT 12
3.2. WP2000: PLATFORM ARCHITECTURE 12
  3.2.1. Overview 12
  3.2.2. External interfaces to the SAMS platform 16
  3.2.3. Software components 17
    3.2.3.1. The Sensor Simulator 17
    3.2.3.2. Surveillance 17
    3.2.3.3. Control 17
    3.2.3.4. Guidance 17
    3.2.3.5. Runway Planning 18
    3.2.3.6. Taxiway Planning 18
    3.2.3.7. Datalink 19
    3.2.3.8. Common information servers 19
    3.2.3.9. Controller HMI 20
    3.2.3.10. Pilot HMI 21
  3.2.4. LATCH 21
  3.2.5. ATS 22
3.3. WP3000: DESIGN AND DEVELOPMENT 23
  3.3.1. Integration phases 23
  3.3.2. Acceptance procedures 26
  3.3.3. Integration details 27
    3.3.3.1. Subscription and notification service 27
    3.3.3.2. Simulation management service 29
    3.3.3.3. Co-ordinate translations 30
    3.3.3.4. Interface descriptions 30
    3.3.3.5. Use of DIS 31
    3.3.3.6. Pseudo pilot station design 32
3.4. WP4000: VALIDATION AND DEMONSTRATION 32
  3.4.1. Validation overview 35
  3.4.2. Added functions validation 35
    3.4.2.1. Labelling 35
    3.4.2.2. Runway Incursion Alert 36
    3.4.2.3. Taxiway Conflict Alert 37
    3.4.2.4. A-SMGCS Data Link 37
    3.4.2.5. Taxiway Planning 38
    3.4.2.6. Runway Planning and Sequencing 38
    3.4.2.7. Guidance 38
  3.4.3. Data logging 38
  3.4.4. Scenarios used 39
    3.4.4.1. Labelling scenarios 39
    3.4.4.2. Runway incursion scenarios 39
    3.4.4.3. Taxiway Collision Alert scenarios 40
    3.4.4.4. Data link scenarios 40
    3.4.4.5. Taxiway Planning scenarios 40
    3.4.4.6. Runway Planning and Sequencing scenarios 40

3.4.4.7. Guidance scenarios 40
3.5. SIMULATIONS SET UP 41
3.5.1. Simulation objectives 41
3.5.1.1. Schiphol simulation 41
3.5.1.2. Heathrow simulation 42
3.5.2. Scenarios 42
3.5.2.1. Schiphol 43
3.5.2.1.1. Participants 43
3.5.2.1.2. Meteorological Conditions 43
3.5.2.1.3. Traffic Sample 43
3.5.2.1.4. Schiphol Airport Layout 44
3.5.2.1.5. Operating Procedures 44
3.5.2.2. Heathrow 44
3.5.2.2.1. Participants 44
3.5.2.2.2. Meteorological Conditions 45
3.5.2.2.3. Traffic Sample 45
3.5.2.2.4. Heathrow Airport Layout 45
3.5.2.2.5. Operating Procedures 46
4. CONCLUSIONS 47
4.1. TECHNICAL AND OPERATIONAL RESULTS ACHIEVED 47
4.1.1. Scenarios performed 47
4.1.2. Feedback from end users 50
4.1.2.1. Traffic Samples 50
4.1.2.2. Miscellaneous 51
4.1.2.3. Pseudo pilot Feedback 51
4.1.2.4. ATS analysis 51
4.1.2.4.1. Visuals 51
4.1.2.4.2. Pseudo pilot station 52
4.1.2.4.3. Controller working positions 52
4.1.2.4.4. Interfacing 52
4.1.2.4.5. Preparation 52
4.1.2.4.6. Command and control 52
4.1.2.4.7. Recording 53
4.1.2.4.8. Platform flexibility 53
4.1.2.5. Feedback from LATCH Crew 53
4.1.2.5.1. Aircraft Model 53
4.1.2.5.2. Cockpit Instrumentation 53
4.1.2.5.3. Cockpit Communications 54
4.1.2.5.4. Cockpit Controls 54
4.1.2.5.5. Out-of-Cockpit Visuals 54
4.1.2.5.6. Moving Map HDD 54
4.1.3. Feedback on the A-SMGCS functions 54
4.1.3.1. Labelled Surveillance function 54
4.1.3.1.1. Schiphol 55
4.1.3.1.2. Heathrow 55
4.1.3.2. Runway incursion alert / control function 56
4.1.3.2.1. Schiphol 56
4.1.3.2.2. Heathrow 56
4.1.3.3. Data link function 57
4.1.3.4. Planning and sequencing function 57
4.1.3.5. Guidance Function 58
4.1.3.6. Controller HMI 58
4.1.4. General feedback on the SAMS platform 59
4.1.4.1. Co-ordination issues 59
4.1.4.2. Availability of the SAMS platform 60
4.2. POTENTIAL BENEFITS 60
4.3. PROPOSALS FOR FURTHER WORK 61
4.3.1. Technical 61
4.3.2. Evaluation 62
ANNEX II – LIST of conferences and presentations 64
ANNEX III – Conflict alert rules 65

REFERENCE DOCUMENTS

<Ref.1> : SAMS Technical Annex, NE 845 204 AN, Iss.0

<Ref.2> : Cost Reimbursement Contract n°AI-97-SC.2097

<Ref.3> : Summary of the RTD Project, NE.852.230 AN. Iss 0

<Ref.4> : Pantelides, R. et.al., *Operational Concept and Functional Specifications*, issue 2, SAMS D1, May 1998, R/NATS/98/007.

<Ref.5> : Schaik, F.J., R. Pantelides, A. Rodenburg, *SAMS Validation Plan*, Amsterdam, November 1999, SAMS D2, C/NLR/98/020.

<Ref.6> : Hesselink, H.H. (ed.), *SAMS Platform Architecture Document*, Amsterdam, August 1998, SAMS D3, C/NLR/98/009.

<Ref.7> : Dubernet, P. et.al., *SAMS User Manual*, Paris, December 1999, C/DEX/99/029.

<Ref. 8>: European Commission, Transport TRD programme, *Guidelines for the Preparation of Reports by Project Co-ordinators*, 1996.

<Ref. 9> : Hesselink, H.H. and H.W.M. van Hedel, *SAMS Integration Plan*, Amsterdam, April 1999, C/NLR/1998/026.

<Ref. 10>: Rodenburg, A. et. al., *SAMS Interface Control Document*, version 1.6, Amsterdam, September 1999, C/NLR/1998/023.

<Ref. 11>: De Jesus, A., *Control Validation Document*, Paris, October 1999, C/DEX/99/023.

<Ref. 12>: Rodenburg, A., *SAMS Control Module – Initial Runway Conflict Alert Rules for Amsterdam Schiphol Demonstration Simulation*, version 0.1, Amsterdam, June 1999, C/NLR/99/024.

<Ref. 13>: Pantelides, R., *SAMS Control Module – Initial Runway and Taxiway Conflict Alert Rules for London Heathrow Demonstration Simulation*, London, April 1999, C/NATS/99/009.

<Ref. 14> Green, M.P., *Technical Analysis of SAMS Simulations*, version 0.D, London, April 2000, C/NATS/2000/xxx.

<Ref. 15> Varona, A., *SAMS Simulator Report*, Madrid, February 2000, C/AENA/2000/xxx.

<Ref. 16> *The Apron and Tower Simulator (ATS)*, www.dlr.de/FF-FL/24/ats/ats.html.

GLOSSARY

ARIA	Advanced Runway Incursion Alert
ATC	Air Traffic Control
ATS	Apron and Tower Simulator
ATM	(1) Air Traffic Management (2) Aerodrome Traffic Monitor
ATOPS	A-SMGS Testing of Operational Procedures by Simulation
A-SMGCS	Advanced-Surface Movement Guidance and Control System
BRIA	Basic Runway Incursion Alert
CORBA	Common Object Request Broker Architecture
DIS	Distributive Interactive Simulation
EC	European Commission
HALS/DTOP	High Approach Landing System/Dual Threshold Operation
HDD	Head Down Display
HMI	Human Machine Interface
ISDN	Integrated Services Digital Network
LAN	Local Area Network
LRVR	Instanteneous Runway Visual Range
LVP	Low Visibility Procedure
MANTEA	MANagement of surface Traffic in European Airports
PFD	Primary Flight Display
PVD	Plan View Display
QFU	Runway magnetic Heading
RIA	Runway Incursion Alert
RPZ	Runway Protection Zone
R/T	Radio Telephony
SAMS	SMGCS Airport Movement Simulator
SID	Standard Instrument Departure
SMGCS	Surface Movement Guidance and Control System
SMR	Surface Movement Radar
STAR	Standard Terminal Arrival Route
TIC	Tower Interface Computer
UDP	User Datagram Protocol
VHF	Very High Frequency
WAN	Wide Area Network

1. INTRODUCTION

1.1. SCOPE

This document is the major document in the series of final reports that are provided for the SAMS project. SAMS (SMGCS Airport Movement Simulator) is one of the major contracts awarded by the European Commission – DG-TREN in the 4th R&D Framework Programme.

This document is organised as indicated in Ref. 8. In chapter 2, the objectives of the project and the means used to achieve them, will be described. Chapter 3 will give a scientific and technical description of the project. The chapter on the conclusion will describe technical and operational achievements, potential benefits of the SAMS project, and will give recommendations for further work.

1.2. BACKGROUND AND RECAP OF THE SAMS OBJECTIVES

A summary of project objectives is given in the public SAMS summary document (Ref.3).

Air traffic control has grown continuously by 4 to 6 % per year over the last 15 years. One of the significant consequences of this rapid air traffic expansion is the attention that is drawn on airports' limited capacity. In Europe, there are presently 50 main airports and 2000 medium or small size airports (as far as traffic is concerned) for which it will be increasingly difficult to cope with additional traffic flows. Indeed, due to environmental policy and economic constraints, it is well understood that although movements are expected to rise significantly, enlarging existing airports or developing new ones will not increase gate-to-gate capacity.

Therefore, in order to cope with such a growth and in order to avoid that airports turn into the bottleneck of the air traffic management, it is essential to improve the existing ATC system by introducing new technologies and new management procedures. A-SMGCS (Advanced Surface Movement Guidance and Control System) is part of this improvement: it deals with the ground segments part and provides means whereby the existing runway, taxiway, and apron infrastructures are used more efficiently.

The European Commission is one of the leading institutions stimulating the research and development of new and improved support facilities in the field of A-SMGCS. Unfortunately, at this stage most of these new developments can only be demonstrated on real airports, with their operational limitations, or in a virtual environment designed and developed by product manufacturers for functional testing. This usually means that only the technical merits of the support tools are put forwards, whereas user acceptance, operational merits, and integration aspects cannot be thoroughly evaluated.

There is a fast growing need in Europe for facilities capable of demonstrating in a comprehensive environment all the advantages of newly developed A-SMGCS technologies (such as those resulting from the projects like DEFAMM, AIRPORT-G, MANTEA, DAVINCI, and DAFUSA). Such facilities would be used by:

- Pilots and controllers to evaluate new A-SMGCS concepts.
- Airport authorities to evaluate key issues before purchasing new A-SMGCS equipment in order to be able to answer question like “will it make the airport more effective whilst reducing the workload for pilots and controllers, without negative side-effects on safety?”
- Aviation authorities to safely evaluate new procedures associated with A-SMGCS before enforcing them operationally.

Moreover, these main players must be involved at a very early stage in order to fully benefit from end-user's feedback during test and assessment of A-SMGCS concepts.

Within this context, the goal of the SAMS project was to design and develop a real-time, man-in-the-loop platform capable of testing and demonstrating new support tools and new A-SMGCS procedures in all weather conditions. This platform offers a highly realistic substitution of the outside views and of the working environment. Among other things, a pilot working environment (LATCH, B747 cockpit), a controller working environment and an outside view projection system of a control tower (ATS = Apron and Tower Simulator) are integrated and connected to the core A-SMGCS simulator.

The three simulators were located at three geographically distributed sites. LATCH was located at DERA in Bedford (UK), ATS at DLR in Braunschweig (D), and the A-SMGCS simulator was based at NLR in Amsterdam (NL). While LATCH and ATS are existing simulators, construction of the A-SMGCS simulator was one activity in the project. Gaining experiences with multi-site simulations through connecting different simulators was part of the objectives of the project.

The project duration is 24 months, for specification, adaptation of sub-systems, integration, test and demonstrations using Heathrow and Schiphol as representative Airport sites. A seven month extension period was used for evaluation of the results and writing the final report.

1.3. SAMS PARTNERSHIP

The SAMS consortium is build up of representatives of industry and research establishments, as well as end users. The consortium consists of five partners from four European countries, four associate partners, and two subcontractors, from six European counties.

The following companies participated:

- Thomson/Detexis (France) – project co-ordinator
- Thomson/ISR (France) – contractor
- DERA (United Kingdom) – contractor
- INTA (Spain) – contractor
- NATS (United Kingdom) – contractor
- NLR (The Netherlands) – contractor
- Aerospatiale (France) – associated partner
- AENA (Spain) – associated partner
- Skysoft (Portugal) – associated partner
- Sofréavia (France) – associated partner
- Delair (Germany) – subcontractor to NLR
- DLR (Germany) – subcontractor to Delair
- Fleximage (France) – subcontractor to Aerospatiale

2. PROJECT OBJECTIVES

This chapter will describe the objectives of the SAMS project. A distinction will be made in the technical description, a detailed description of A-SMGCS subsystems, and the strategy followed to achieve the objectives.

2.1. A-SMGCS CONTEXT

Currently, operational procedures on the surface of an aerodrome depend on pilots, air traffic controllers, and vehicle drivers using visual observation of the location of the aircraft and vehicles in order to estimate their respective relative positions and risk of collision. Pilots and vehicle drivers rely on visual aids (lighting, signage, and markings) to guide them along their assigned routes and to identify intersections and holding points issued by the controller. During periods of low visibility, controllers must rely on the pilot's RTF 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.

Within the frame of the SAMS project, A-SMGCS is divided in the following functional areas:

- Surveillance
- Control
- Planning
- Guidance

Currently the human operators are helped in their tasks by some automated tools with rather limited capabilities.

For instance, in the surveillance area, a surface movement radar (SMR), replaces the eyes of a controller to a certain extent: the SMR gives only the position of the objects on the airport platform, not their identity. The controller has to correlate the reported positions with the identities gathered elsewhere and keep in mind the associations.

Similarly in the control aids area, the controller has to monitor with his eyes and brain to ensure that aircraft and vehicles are properly separated and do not enter restricted or prohibited zones.

In the field of planning, the controller mentally chooses which runway will be used for each flight and which taxiways will be taken to route an aircraft on the airport platform.

In the guidance area, the controller has to switch on and off manually the guidance means (lights, signs, stop bars…) to guide the aircraft on the airport taxiways.

There is a fast growing need in Europe for facilities capable of demonstrating in a comprehensive environment all the advantages of newly developed A-SMGCS concepts. In fact:

- Pilots and controllers request a platform that let them evaluate new A-SMGCS concepts.
- Airport authorities wish to be able to evaluate a key issue before purchasing new A-SMGCS equipment: will it make the airport more effective without any negative side-effect on safety or on pilots and controllers workload?
- Aviation authorities wish to safely evaluate new A-SMGCS procedures before enforcing them operationally.

Within this context, the SAMS project is therefore dedicated to the design and development of a platform for a real-time, man-in-the-loop A-SMGCS simulation. It includes simulation of the air/ground environment and, owing to an A-SMGCS simulator, is capable of testing and demonstrating new support tools and/or new A-SMGCS procedures in all weather conditions.

As in real life, both pilots and controllers derive major part of the necessary information from visual observation, which is enriched by automated information processing tools (such as radar displays). The SAMS platform is connected to simulation tools that offer highly realistic outside views and of the working environments. A pilot working environment, a Boeing 747 cockpit, located in Bedford (UK) and a controller working environment including an outside view projection system of a Control Tower, located in Braunschweig (D) are integrated and connected to the A-SMGCS simulator, located in Amsterdam (NL).

The SAMS project simulates outside visuals and procedures of Amsterdam Airport Schiphol and London Heathrow.

2.2. ENHANCEMENTS STUDIED IN THE SAMS PROJECT

In each of the identified A-SMGCS function areas, SAMS intends to support controllers and pilots.

In the surveillance area, the automatic labelling of the traffic situation presented to controllers will relieve them from the mental effort of identifying the traffic positions reported by SMR. Moving map displays, which show the aircraft locations over the airfield, can support pilots.

In the control area, automated tools will give the controller alerts in due time about runways or prohibited areas incursion by non-authorised aircraft and vehicles. Hazardous crossings between mobiles leading to collisions (e.g. insufficient wing tips separation in case of two very large aircraft crossing) can also be detected in advance and signalled to the controllers and pilots.

In the area of planning, departure sequences and runway allocation can be computed automatically and proposed to controllers. Routes from the gate to the runway for outbound flights and from the runway to the gate for inbound flights can be computed automatically.

For the guidance area, automatic switching of lights and signs of the lighting system will be integrated with the retained taxiway routes for any flight. Datalink facilities can provide information transfer from ground to the aircraft. Pilots can be supported by presentation of guidance information their moving map displays.

The SAMS project was aimed at facilitating a simulation facility to enable research into new A-SMGCS procedures and functions. The actual performing of evaluations with those procedures and functions was not part of the SAMS project, instead, a follow up project, ATOPS (A-SMGS Testing of Operational Procedures by Simulation) was running more or less simultaneously. Connecting different simulators at geographically different places into a real-time A-SMGCS environment, was one of the objectives of the project.

2.3. MEANS USED TO ACHIEVE THE OBJECTIVES

The work performed in the SAMS project was structured into 6 main Work Packages (WP), which were:

WP 1000: Operational Concept. Its goal of this work package has been to define the operational objectives of the demonstration (key functions to be simulated) as well as the exact role of end-users in the system (pilot and controller). From this, the SAMS platform functional specification has been derived. The associated validation plan was elaborated in this work package

WP 2000: Platform architecture. The objective of this work package has been to define a comprehensive hardware and software architecture for both the working environment simulation facilities and the A-SMGCS simulator. This includes a definition of the airport database. Test plans and acceptance procedure for each sub-block of the architecture have been defined in this work package.

WP 3000: Design and development. This work package has been dedicated to the realisation of the traffic and environment generator, of the A-SMGCS simulator and to their integration with existing simulation facilities. Already existing functions (background of previous projects) have been adapted. Other ones have been developed from scratch.

The integration of the SAMS platform has been performed in several consecutive steps. A first integration has taken place at ISR premises and was limited to a subset of the A-SMGCS components. The complete integration of the SAMS A-SMGCS has been performed at NLR premises. After that, the other simulators (LATCH and ATS) have been connected to the A-SMGCS platform in order to facilitate the complete SAMS platform.

WP 4000: Validation and Demonstrations. Objective of this work package has been to validate the overall SAMS platform and to perform two full-scale demonstrations for operational airport sites (Schiphol and Heathrow). Demonstration results have been analysed within this work package.

WP 5000: Report and Conclusion. This work package has been dedicated to the release and dissemination of the project final report.

WP 6000: Management. This project-long work package has been devoted to the management of the overall project. It encompasses set-up of a management structure, project co-ordination, tracking of work progress, periodic project meetings, preparation of periodic EC reviewing, administrative and financial reporting to the EC.

2.4. EARLY ASSESSMENT OF THE SAMS ACHIEVEMENTS

The full range of objectives of the SAMS project appeared to be too ambitious in time and budget. Delay in the project caused time pressure on the use of the simulators, the arrangements with operational controllers and pilots, and budget overflows, so that the consortium considered reducing functionality of the A-SMGCS platform. In consultation within the consortium and with the customer, it was therefore decided to stop the development of the departure sequencing function, to stop the integration of the guidance function, to not evaluate the routing function, and to use only limited data link functionality.

The SAMS platform eventually consisted of the three simulators, LATCH, ATS, and the A-SMGCS simulator.

Both LATCH and ATS have been fully facilitated for simulation of the airports of Schiphol and Heathrow and were equipped with additional facilities. The facilitation of the simulators concerned the provision of outside visual databases, the construction of pseudo pilot stations for ATS, creation of scenario databases, and access to the simulators for integration work, testing, and during the simulations. Additional equipment in the simulators was necessary for communication with other simulators, both for software data exchange and simulated R/T between LATCH and ATS, and for facilitating the A-SMGCS functions. The HMI (Human Machine Interface) of the A-SMGCS platform was actually located within the ATS facility (hardware and software).

The A-SMGCS platform contained the following functions:

- Surveillance was fully operational through a map display of the airport over which aircraft and vehicles were moving. This map display was available for both the controllers and pilots.
- Electronic flight strips were available for the controllers.
- Runway incursion alert was available for the controllers. Information about runway incursions could be send to the pilots via simulated data link.
- Taxiway routing was available for controllers.
- A dedicated HMI was available for controllers and pilots.

3. SCIENTIFIC AND TECHNICAL DESCRIPTION OF THE PROJECT

This chapter covers the work performed in the SAMS project by describing the consecutive work packages. The project consisted of work packages for capturing user requirements, defining an architecture, construction of the simulators and validation of the scenarios that were prepared. The main results of the simulations performed will be described in the finishing section.

3.1. WP1000: OPERATIONAL CONCEPT

The goal of the work package “Operational Concept” is to define the operational objectives of the SAMS-demonstration (key functions to be simulated) as well as the exact role of end-users in the system (pilot and controller). A functional specification and a validation plan are derived from this description.

Generation of the operational concept document (Ref. 4) was acheived by performing:

1) A functional breakdown of the job of a controller and (pseudo) pilot in a simulation.

2) A functional breakdown of the simulation functions that allow the controller and (psuedo-) pilots to act realistically in the simulation.

3) A functional definition of the controller assistance tools which were to form part of the SAMS platform.

4) A cross reference at the functional level to demonstrate that functions listed in (1) and (2) are correctly matched and that functions specified in (3) match the operational development objectives of the project.

Steps (1) to (4) above were performed for both target airports, namely Amsterdam Schiphol and London Heathrow.

Work to generate the operational concept document was structured as follows:

WP 1100 Definition of Objectives: This defined the functions required of the Airport Movement Guidance and Control Simulator and was subdivided as follows:

WP 1110 Controllers and pilots roles: This defined the ATC and pilot tasks that the Airport Movement Guidance and Control Simulator will be required to support.

WP 1120 Simulator Functionality: This defined the functionality to be required of the Airport Movement Guidance and Control Simulator.

3.2. WP2000: PLATFORM ARCHITECTURE

The objective of the work package “Platform Architecture” was to define a hardware and software architecture for both the working environment simulation facilities and the A-SMGCS simulator. The SAMS architecture is described in Ref. 6.

3.2.1. Overview

In the real world pilots and controllers obtain their information for a very large part from visual observation (including visual aids for pilots) and from voice communication between pilot and controller. A new situation will exist when new A-SMGCS tools will be used. In SAMS, connected to the tower-equipment, an A-SMGCS simulator has been introduced that provides, to both controllers (via direct link) and pilots (via a data uplink facility), the extra information required. Pilots and controllers will both be informed by means of an HMI (Human Machine Interface), in most cases consisting of a monitor and an input device, and through voice communication.

Figure 1 describes the global architecture of SAMS. In SAMS each facility has been substituted with a simulator. SAMS consists of the following major components:

- The LATCH cockpit simulator, located in Bedford (UK).
- The ATS tower simulator, located in Braunschweig (D).
- An A-SMGCS simulator, located in Amsterdam (NL).
- A datalink facility, between the A-SMGCS simulator and LATCH.
- A voice channel, between LATCH and ATS.

In figure 1, we also find:

- An HMI for the pilot, which will be placed in the cockpit simulator.
- HMI for the controller, which will be placed at the controller working position.
- Procedures and operational concepts. Although not part of the SAMS project, the system must be prepared to be configurable for different procedures and concepts.
- Additional functionality needed to perform simulations such as an environment generator, simulation command and control, logging, and analysis.

In figure 1, displayed in yellow are the actual simulation facilities. For LATCH and ATS, additional hard- and software is required to enable their simulation function, e.g. aircraft performance models. The functions displayed in red show additional facilities necessary to the SAMS platform to connect the simulators and to enable evaluations with the platform.

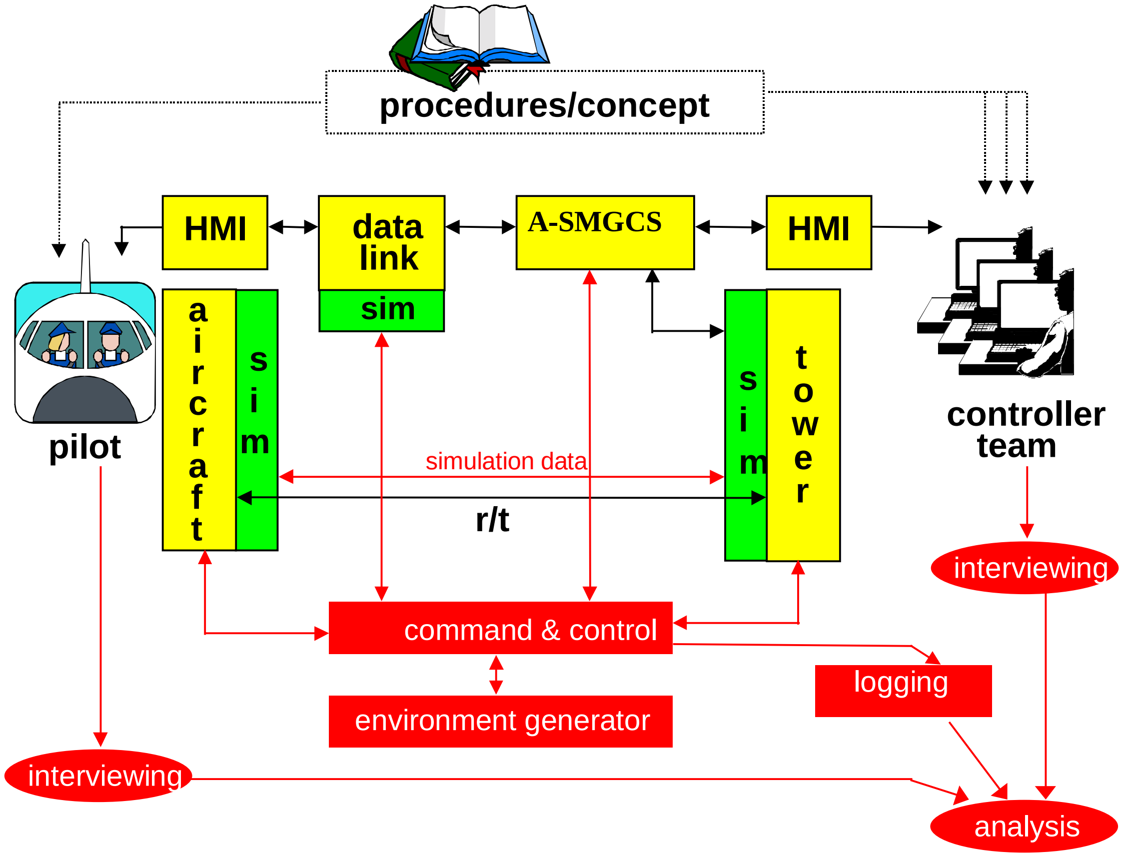

Figure 1, Global architecture of SAMS.

The information flow between the different SAMS simulators and within each facility is depicted in figure 2. The same colour coding as in the previous figure is used.

The A-SMGCS simulator is divided into the four identified functions.

For LATCH, the airport environment must be simulated. The environment consists of the airport lay out and meteorological information, which are both processed to be displayed at the cockpit outside visual screens.

For ATS, like for the flight simulator, the airport environment must be simulated. Within ATS, the traffic for the simulation is generated (except for the LATCH movements). Traffic generation is based on actions from pseudo pilots, who respond to R/T from controllers. Aircraft models are available in ATS to simulate realistic behaviour.

Communication between the simulators consists of environment data (all simulators must simulate the same airport with the same meteorological conditions), R/T, and positional information from the ATS generated traffic and the positions from LATCH.

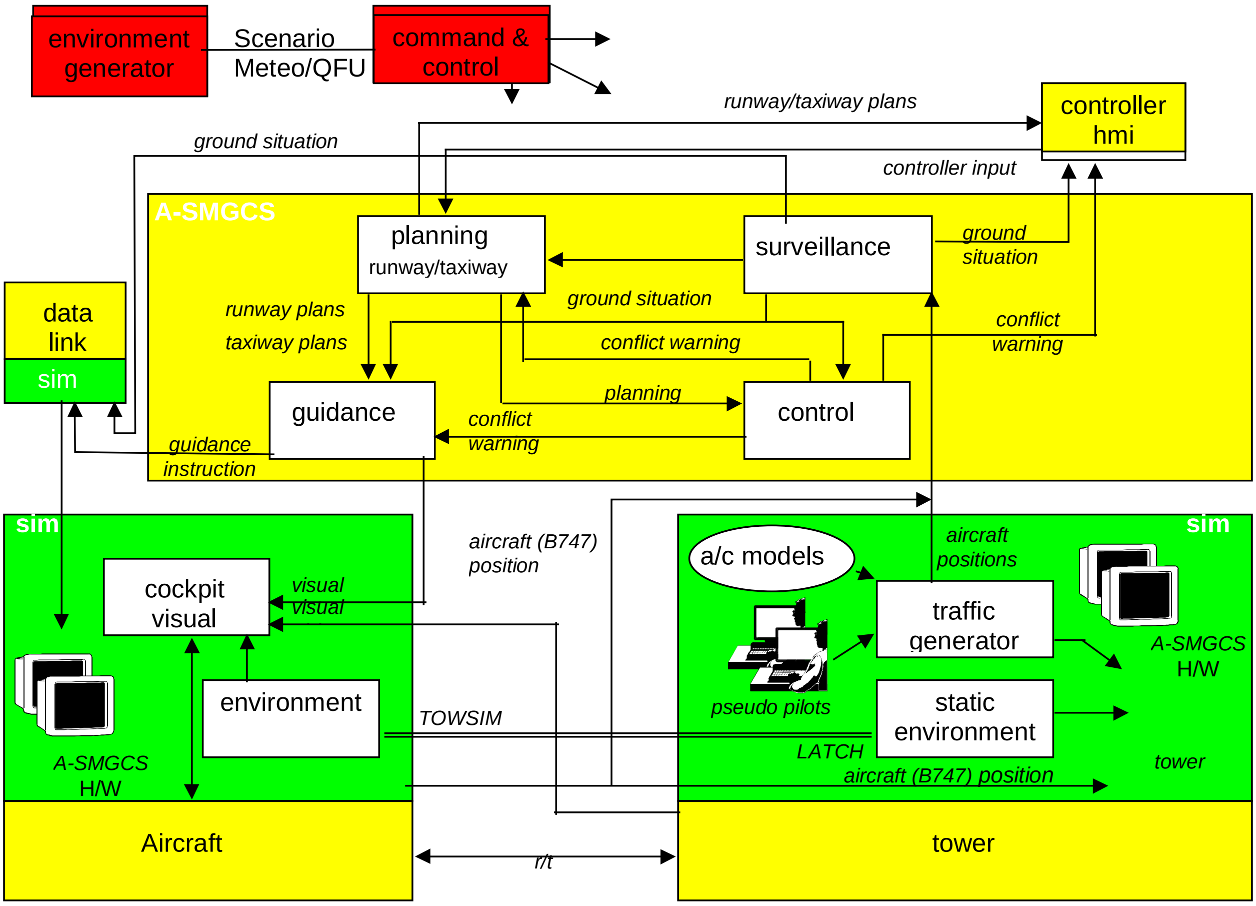

Figure 2, SAMS information flow.

The A-SMGCS functions are further subdivided according to a software client/server architecture. This means that software components function autonomic and pass information through requests and subscriptions. CORBA (Common Object Request Broker Architecture) middleware was used to enable communication between different software components. The components behave as clients when they request information from other components, e.g. the control function will request position updates from surveillance. The components behave as servers when they provide information to other components. CORBA servers are displayed in purple in figure 3.

Communication between the different simulators is achieved through the DIS (Distributed Interactive Simulation) and UDP (User Datagram Protocol) protocols. All DIS communication was relayed via the TIC (Tower Interface Computer), located in Amsterdam, that was connected via dedicated ISDN lines to Bedford and Braunschweig. A special filter program was necessary to translate DIS to UDP and vice versa.

The ISDN lines were also used to pass HMI information between Amsterdam and Braunschweig. Although the HMI is a logical part of the A-SMGCS simulator, the displays were actually located in Braunschweig since controllers have to use both the outside visuals and A-SMGCS HMI information at the same location. The workstations that were running the HMI were moved together with the displays, so that basic actions on the display such as moving windows and zooming in and out could be performed locally. This relieves data transfer over the ISDN line, which now only transfers A-SMGCS information to and from the HMIs.

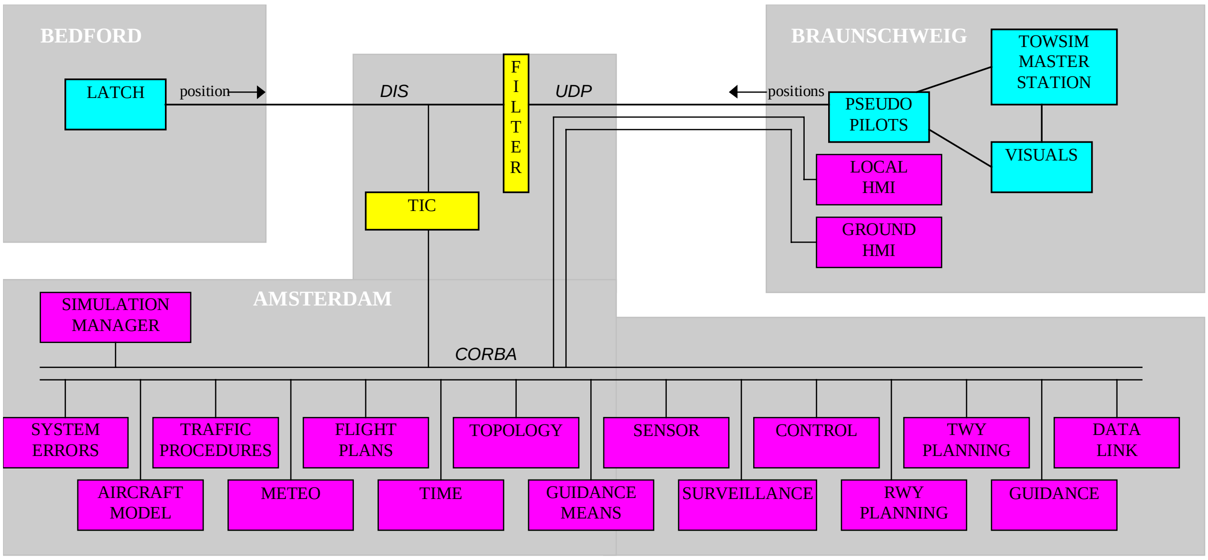

Figure 3, SAMS client/server architecture.

The SAMS platform consisted of several workstations from different manufacturers with different operating systems. The full platform consisted of the following:

- ATS equipment was running on Silicon Graphics and PC/NT.
- LATCH equipment was running on PC/NT, PC/Linux, and Silicon Graphics.
- The A-SMGCS platform was a network of 7 work stations:
    - One Silicon Graphics machine was running the conversion filter program.
    - One Silicon Graphics machine contained the TIC and simulation support functions: simulation manager, system errors, aircraft model, traffic procedures, meteo server flight plans, time server, and data link.
    - Two SUN workstations were running to support the ground and tower HMIs.
    - One SUN workstation contained the topology, guidance means, taxiway planning, and runway planning servers.
    - One HP workstation contained the guidance function.
    - One PC/NT contained the sensor, surveillance, and control functions.

3.2.2. External interfaces to the SAMS platform

The SAMS platform exchanges information with the outside world of the simulators. As can be observed from the figures in the previous section, this can be divided into environment data, prepared off-line and needed to run the simulations smoothly and human interaction during the simulations from pilots and controllers. The aspect of operational procedures as external entity has been left out here, since this would be taken up later in the ATOPS project.

Environment data is prepared off-line and describes one simulation session completely. Data consists of airport to be simulated (topology and 3D outside view files), time of day, meteorological information, flight plan descriptions, corresponding flight strips, and the sensor quality files for track lost and label swap experiments. Different combinations of data files could be used in combination to create a new scenario. It appeared of major importance that flight plan scenarios were not repeated too often, since controllers are well capable of recognising them during the simulations.

Controllers and pilots interacted with the system by means of their HMIs. The HMIs mainly functioned for information provision. They are described in detail later in this document.

3.2.3. Software components

This section gives a general description of the A-SMGCS software components that have been integrated in the A-SMGCS simulator. Each sub-section will describe one of the functions.

3.2.3.1. The Sensor Simulator

The objective of the Sensor Simulator is to generate a realistic ground situation with regards to the simulated data provided by the traffic generator. This ground situation will be established by three simulated sensors (an ASDE sensor, a Mode-S multi-lateration system and a D-GPS system) and transmitted as tracks to the surveillance subsystem.

The traffic samples received from the Traffic Generator are formatted in sensor outputs (one per simulated sensor) to simulate the perception by the sensors of aircraft or vehicle on the airport surface. All sensors take into account the airport topological information (building locations) and are designed to receive configuration commands from the Environment Data Generator. The outputs are forwarded to the surveillance component.

3.2.3.2. Surveillance

The surveillance subsystem of the SAMS platform is composed of a data fusion and labelling system responsible for the elaboration of the ground situation in terms of kinematic information (position, velocity, heading) and mobile (aircraft or vehicle) identification. The output data (enhanced airport ground situation) of the surveillance subsystem will be forwarded to the routing subsystem, the guidance subsystem, the control subsystem and the controller HMI. A reduced traffic situation describing the traffic in the vicinity of the DERA aircraft will be sent to the data-link and from thereon to the pilot HMI.

The labelling is done, on one hand automatically by associating the elements received from the sensor simulator and the elements received from the flight management, and on the other hand, manually by controller assignation of identification to tracks from the Controller HMI.

An extra « touch down » information, calculated based on the altitude information, is delivered to the guidance subsystem to initiate the guidance processing of arriving aircraft.

3.2.3.3. Control

The goal of the control subsystem is to detect possible conflicts on the airport surface with regard to the enhanced airport ground situation, to detect route deviations of aircraft with regards to their assigned routes, and to generate associated warning messages (alerts) to the concerned subsystems. The input data of the control subsystem is composed of the enhanced airport ground situation delivered by the surveillance subsystem and the aircraft assigned routes delivered by the routing subsystem. The warning messages (alerts) are delivered to the routing subsystem, the guidance subsystem and the controller HMI whenever a conflict has been detected.

Conflicts between two or more tracks are subdivided into a taxiway alerting function, which checks for wingtip clearances and intrusions into localizer sensitive areas, an a runway incursion alert to safeguard the open runways. References 12 and 13 describe the conflict alert rules for Schiphol and Heathrow respectively. Annex III gives an overview of conflict alert rules.

3.2.3.4. Guidance

The Guidance Processor is responsible for the facilities, information, and advice necessary to provide continuous, unambiguous and reliable information to pilots and vehicle drivers to keep aircraft and vehicles on their assigned surface routes. This includes the automated control of the ground guidance aids and the transmission of guidance messages to suitable on board pilot/driver assistant systems.

Ground guidance aids are taxiway centreline lights and stop bars. Both of these can be switched on and off in front of the aircraft or vehicle. The guidance processor also generates onboard messages (displayed in the aircraft cockpit). These messages are generated in accordance to the routes assigned for each mobile by the Planning function or the Controller, taking the enhanced ground situation into account.

3.2.3.5. Runway Planning

The goal of the runway planning is to maximise the number of departing a/c per hour giving priority to slotted flights and complying with separation criteria as well as runway operating rules. The runway departure planning is implemented only for Heathrow Airport. The departure sequence may include multiple line-up departures. The planning horizon will be 20 minutes.

Re-planning, triggered by changes in flight status, will occur if:

- The sequence is rejected by the taxi planning because one or more of the a/c cannot achieve the assigned take-off time in this case, the taxi planning will give the new expected take-off times of the a/c so that a new sequence can be computed.

- A taxiing a/c is deviating from its taxi plan: the runway planning will be informed of it by the taxi planning which will give a new expected take-off time.

The departure sequence is sent to the Controller HMI. The controller can change the order of or give priorities to flights through the Controller HMI. Such a request can be sent by the controller along with call signs of concerned aircraft and their new position in the sequence.

The Runway planning uses a list of active runways supplied by the Airport Topology component, and a list of flight plans of departing aircraft, supplied by the Flight Management component, to which it allocates a take-off time within the CFMU time slot or close to the estimated take-off time. The flight status (inactive, pending, active, live, terminated) is included in the flight plan. Only pending flights are input to the Runway Planning.

The runway planning will also check that the aircraft can take off with the current cross and tail wind. Meteorological data consist essentially of air and visibility conditions as separation criteria and runway operating rules depend on this information.

3.2.3.6. Taxiway Planning

The main objectives of the taxiway planning subsystem are:

- To define a route for each aircraft in order to reach its destination on the airport with respect to its flight plan constraints, taking into account other airport traffic.

- To allow for re-planning, minimising the impact on the rest of the traffic in case of non-respect of the first established plan or in case of conflict.

In order to provide the controller with a quite realistic plan and to avoid disturbing him with useless validation actions, the taxiway planning subsystem will provide the plan during push back time for outbound aircraft and during landing time for inbound aircraft.

The starting and ending location and times of aircraft movements are extracted by the Taxiway Planning from the flight data supplied by the Flight Management component. The best departure times of outbound aircraft are extracted from the runway sequences supplied by the Runway Planning component. The airport tarmac possibilities and are extracted from topology data supplied by the Airport Topology component and the airport movement regulations from the Airport Procedures component. The influence of meteorological conditions on routing regulations are computed with the meteorological data supplied by the Meteo component,

The aircraft performances and characteristics are extracted from the aircraft performance data supplied by the Aircraft Performance component and taken into account to check that an aircraft can use a given taxiway block because of its size or weight.

The deviations of the actual path followed by an aircraft from its cleared route are known from the conflict warnings supplied by the Control component. In this case, the current position of the aircraft is extracted from the enhanced ground situation supplied by the Surveillance component (the taxiway route origins will be computed from these positions).

The controller can make changes to the taxiway routes through the Controller HMI. A notification is sent to the Controller HMI to inform the controller when the Taxiway Planning does not find a feasible routing for the aircraft.

The assigned routes are sent to the Guidance function to enable it to guide the aircraft, to the Control Aids component to check for deviations, and to the Controller HMI for display allowing the controller to make route modifications.

3.2.3.7. Datalink

The data link simulator module provides the communication of advisory and ground situation information from the A-SMGCS guidance module to the aircraft (LATCH cockpit). The transfer of these messages by data link will allow remote guidance to be carried out, even in low visibility conditions, whilst contributing to a reduction in controller and pilot workload. The module provides consistent system behaviour as if data link equipment and infrastructure were actually in place.

3.2.3.8. Common information servers

Common information is information that is used by most of the subsystems. This information is provided by the “Common Information Servers”. The “Common Information Server” is not one physical database or server. It consists of several data providing and processing systems:

- Airport topology server
  The Airport topology server stores all the geometrical information and properties of the fixed equipment of the airport platform (such as runways, taxiways, aprons, gates, buildings, obstacles, signalling equipment, etc.). The properties of runways and taxiways and their connectivity are used by the HMI and the Taxiway Planning component.

- Traffic procedures server
  The Traffic procedures server describes nominal movement procedures like taxi routes, SIDS, STARS, and pushback procedures.

- Aircraft performance server
  The aircraft performance server describes aircraft type and corresponding aircraft performance data. It provides properties of the possible types of aircraft hosted on the airport platform such as cross and tail acceptable wind speeds, weight, size, ground dynamic capabilities, etc. It also computes the landing, take off and braking times and distances from the aircraft weight and runway values as needed by the planning components.

- Meteorological server
  The Meteorological server supplies information about weather conditions. The server stores the properties of the air surrounding the airport platform. Updates of the property values are received from the Environment Data generator. The visibility conditions, the temperature, the humidity influence directly the separation requirements and the performances of the aircraft and so are used by the planning components to compute the runway sequences and airport routes. The local pressure is used by the Surveillance component to compute the altitude of the transponder (Mode C) aircraft.

- Flight plan server
  The Flight plan server provides access to information with respect to flight plans. It holds all flight data, and

stores, updates and distributes flight data. It updates the allocated parking area received from the Environment Data Generator and the allocated runway received from the Runway Planning. It maintains the current clearances received from the Controller HMI and keeps the estimated take off time, estimated runway time, and estimated off block time as well as the runway point (entry for outbound or exit for inbound) calculated by the Runway Planning component

- System error server
  The System error server provides data to configure the behaviour of some functions e.g. surveillance errors.

- Time server
  The Time server supplies the reference-time for all SAMS systems.

In addition to the common information servers, there are three operating components:

- Supervisor server.
  The Supervisor server provides technical control of the subsystem. This server has the ability to configure the components over the available hardware before a simulation starts. Furthermore, it controls the start and stop of the simulations by synchronising the execution, initialisation, and starting of the servers.

- Transport and exchange of data through the A-SMGCS simulator are processed through a CORBA ORB.

- Transport and exchange of data between the A-SMGCS, the cockpit, and the tower simulator are processed through the DIS protocol.

3.2.3.9. Controller HMI

The controller HMI supplies the controller with information regarding the planning of traffic at the airport (e.g. arrivals and departures lists), airport status, current traffic situation, conflict situations, assigned routes etc. The HMI also allows the controller to interact with the A-SMGCS platform and access the advanced features.

The main inputs of the controller HMI server are:

- Flight data, received from the Flight management, includes changes in the status of the flight plans and modification of the estimated times computed by the runway planning component.

- Ground topology, received from the Airport topology component, in order to display an airport map over which on overlay is made with assigned routes, taxiway segments and gate locations.

- Enhanced ground situation, also overlaid over the airport map, received from Surveillance, in order to display the labelled traffic on the airport.

- Air traffic, received from Surveillance, which is dedicated for the tower controller in order to manage air arrival and departure traffic.

- Runway sequences, received from the Runway Planning function.

- Conflict warnings, received from the Control component, in order to display the taxiway/runway/plan conflicts.

- Stop bar statuses, received from Guidance.

- Meteorological data received from the meteorological server.

Through use of the HMI, the controller is able to:

- Change the stop bar status to stop or start aircraft in case of a conflict.

- Change the runway or taxiway status, when the controller opens or closes a runway or taxiway.

- Change runway sequences.

- Change routes, when the controller manually wants to assign a route or when the provided one is not deemed correct.

3.2.3.10.Pilot HMI

The Pilot HMI enables the pilot to receive messages from the controller and the A-SMGCS platform. It will show a map of the airport in the direct vicinity of the aircraft itself, enhanced with the positions of other aircraft, routing information, and the status of airfield lighting and stop bars.

3.2.4. LATCH

The SAMS project made use of the DERA B747 ‘LATCH’ flight simulator to include pilots in the loop. The flight simulator features a realistic view of the world outside of the cockpit as well as all the instrument panels found in an actual B747. The cockpit is based on a generic Boeing 747 with two pilot positions, representative cockpit controls/instrumentation including Primary Flight Head Down Display (HDD) and simulated out-of-cockpit visuals. Furthermore, it was equipped with a SAMS pilot HMI, which relays A-SMGCS messages (e.g. taxiing instructions and runway incursion warnings) from the SAMS platform to the pilots and vice versa.

The objectives for the involvement of LATCH in the SAMS platform were:
- To provide a pilot-in-the-loop capability for the SAMS platform, thus enabling assessment of the pilot’s interaction with A-SMGCS information provided via cockpit display panels instead of traditional voice communications.
- To demonstrate the use of LATCH in a simulated ATM environment, distributed across a Wide Area Network (WAN) configuration.

Note that the A-SMGCS functionality (other than display of the positions of other aircraft on the moving map) has not been implemented in the SAMS platform.

The LATCH system is implemented using a networked configuration of PCs (Windows 95/NT and Linux) and Silicon Graphics workstations. LATCH communicated with the rest of the SAMS platform via an ISDN 2 connection to the TIC computer at NLR. The communications to/from NLR use the Distributed Interactive Simulation (DIS) protocol.

The LATCH operator communicates with the LATCH pilot(s) via a headset intercom system, which is capable of being connected to operators of the other SAMS subsystems via a standard telephone link. The LATCH simulator provides the capability to video record simulation trials, with superimposed out-of-cockpit visuals and moving map view, and a sound track of the headset communications.

The SAMS simulation scenarios were based on realistic traffic situations at Heathrow and Schiphol airports. Visual databases of both airports, along with aircraft models representing simulated aircraft generated by pseudo-pilots based at the ATS platform at DLR in Braunschweig, were used to simulate out-of-cockpit views. The Heathrow visual database incorporates airport lighting patterns (runway, taxiway and apron lights, and taxiway stop bars) which were capable of being controlled by the A-SMGCS guidance and control subsystems, although the functionality to do this has not been envisaged in the SAMS platform.

The LATCH HDD displays a “moving map” plan view of the airport in use, provided in the cockpit. Superimposed on the moving map are symbols representing the other simulated aircraft taking part in the simulation. It was possible to display on the moving map the status of taxiway stop bars, but also the functionality to do this has not been envisaged in the SAMS platform.

Pilot requests for pushback or taxi clearance are initiated via a data link button panel installed in the cockpit. A “clearance granted” message, issued by ground controllers based at the ATS, could be displayed in the moving map message area. Followed by a “clearance granted” message, the pilot issues an acknowledgement via the button panel, although the functionality to respond to acknowledgements was not implemented in the SAMS platform.

Following the granting of a clearance to taxi, LATCH provides the possibility to display a taxi plan, issued by ground controllers based at the ATS, on the moving map as a series of connected taxiway segments.

3.2.5. ATS

The SAMS platform used the DLR Tower Simulator, ATS, to include air traffic controllers in the simulations. The Tower Simulator features a simulated outside view and realistic controller working positions. The SAMS controller HMI, to allow the controllers to interact with the A-SMGCS features of the SAMS platform, enhances the working positions. Figure 4 gives an impression on the outside view quality of ATS.

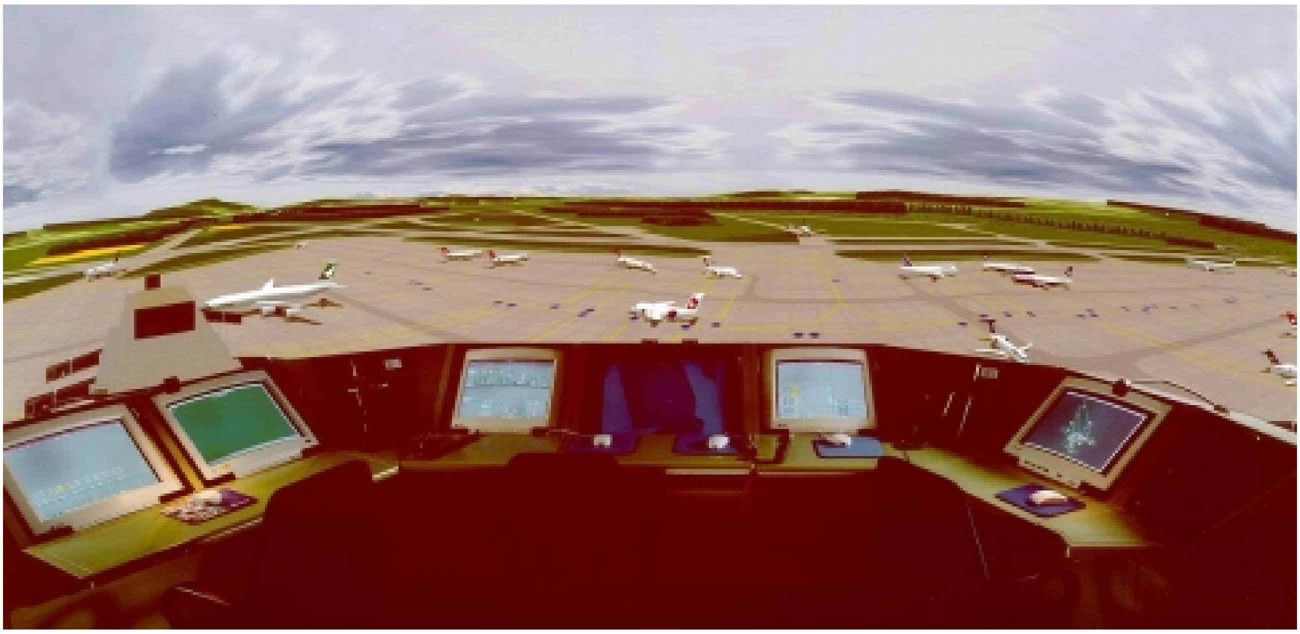

Figure 4, 300° Tower Simulator at DLR.

ATS (Ref. 16) is used for research and development purposes for vision-based air traffic control in the vicinity of airports, i.e. for tower, apron, and ground control.

ATS consists of a dynamic module that generates aircraft movements according to aircraft dynamic models and a visual system that generates and displays the synthetic vision. The simulated aircraft are controlled by pseudo pilots in a separate control room, who communicate with the controllers via a simulated radio transmission line. The ATS supervisor uses a master station to control the simulation.

A variety of editing tools is available for modelling and for the preparation of simulations. ATS has been developed for DLR in co-operation with DaimlerChrysler Aerospace. The visual system consists of a six-channel image generator based on a Silicon Graphics Onyx 2 computer and two projection systems in separate halls where the images are projected on a spherical screen of six meters in diameter. The projection systems are identical with the exception of the visual angle of 200° and 300° horizontally displaying four and six visual channels respectively. SAMS used the 300° projection only. The vertical angle of vision is 48°. Databases of Amsterdam Schiphol and London Heathrow Airport were made available by DERA and projected using the 300° system. The actual 300° selection out of the available 360° could be changed easily before each demonstration run.

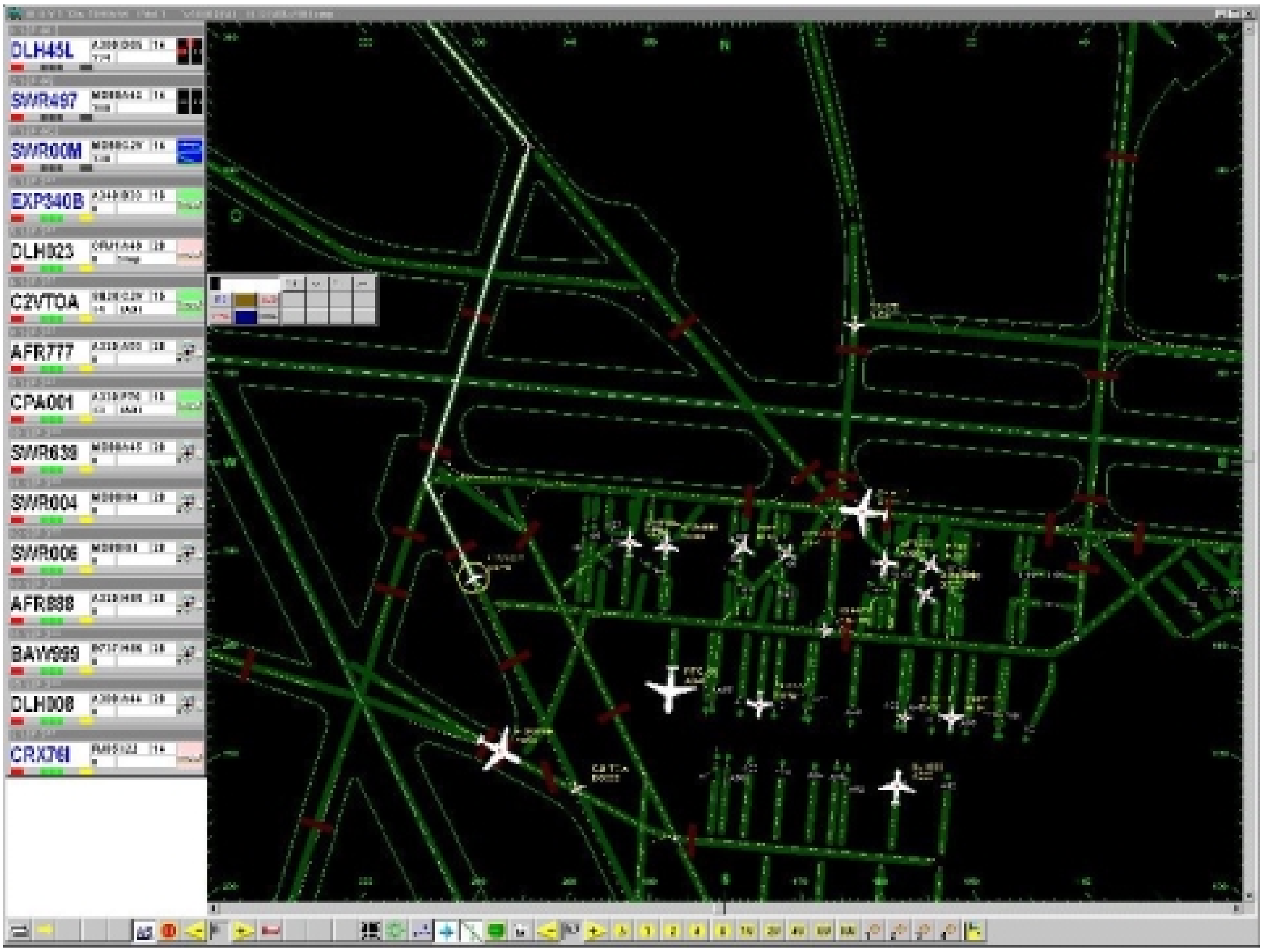

Figure 5, Pseudo pilot station.

Up to six pseudo pilots participated in the simulations entering the control clearance to a terminal via mouse and keyboard and reading back the clearances. Each pseudo pilot may control up to 30 aircraft (in SAMS the maximum was 10 due to intensive VHF communication and taxi work load). The association between pseudo pilots and controller working positions is arbitrary with respect to the different number of aircraft that may be under each controller's responsibility. Figure 5 shows a typical pseudo pilot position.

A variety of editing tools was used for the preparation of the experiments. Flight plan and procedure editors were used to schedule the behaviour of each aircraft, including its parking position, pushback and taxi procedure, and the preferred runway and departure or arrival route. At any time, the pseudo pilot could overrule this pre-planned behaviour. A map editor was used to generate the airport model.

The master station was used by the supervisor to start and terminate the simulation, to load the desired traffic scenario, and to choose the simulation time as well as the visibility conditions. The master station is also equipped with pseudo pilot functionality so that the supervisor could take over control of certain aircraft. The simulator could be frozen on demand, and continued thereafter.

3.3. WP3000: DESIGN AND DEVELOPMENT

The work package “Design and Development” was dedicated to the realisation of the A-SMGCS simulator and its integration with existing simulation facilities, LATCH and ATS. Existing functions have been adapted, while some have been developed from scratch.

3.3.1. *Integration phases*

The integration of the components was planned in several consecutive steps. A pre-integration of some of the A--SGMGC servers was performed on the existing MANTEA (MANagement of surface Traffic in European Airports) platform. This activity could be performed in Paris with the French partners in the project. The final SAMS A-SMGCS platform was assembled in Amsterdam.

The SAMS components that have been integrated in the pre-integration step were:

- Controller HMI.
- Runway Planning.
- Taxiway Planning.
- Airport topology.

In order to perform the integration and test the servers, a reduced A-SMGCS platform was set up with the following components adapted from the ISR MANTEA platform:

- Simulator.
- Meteo.
- Surveillance.
- Flight management.
- Aircraft Performance.
- Logging facilities.

The MANTEA simulator allowed to feed traffic, flight plans, and meteorological data to the A-SMGCS components. Inputs could be made directly on the Controller HMI and so it was possible to satisfactorily test the SAMS components. With this approach, it was possible to test and qualify the ISR SAMS components before integration at NLR premises. The component from Aerospatiale has been integrated in the same manner.

The actual integration of the A-SMGCS platform phase took place in NLR premises. The integration has been divided into five phases.

Phase 1: In this phase, ISR has replaced all the common servers from the pre-integration by the real SAMS common servers. The ISR servers provide the functionality for Human Machine Interface (HMI) and the planning functions.

Phase 2: In this phase new features, like the supervisor facility from NLR and the subscription service, have been added to the platform. The servers were developed independently from the SAMS servers and could be tested off-line.

Phase 3: This phase concerned the integration of all Thomson/Detexis servers with the NLR common servers and the simulation facilities. The A-SMGCS servers from Thomson/Detexis concern the surveillance and control functionality, which are needed as basic servers for the planning and guidance servers.

Phase 4: In this phase, the airports of Heathrow and Schiphol have been implemented in the platform. Since the pre-integration in Paris had been performed for different airports (Paris and Rome), the common servers needed to be switched for the SAMS relevant airports.

Phase 5: In this phase, the Guidance Server and the Datalink Manager (CORBA part and RTSN software) have been added. The result of this phase is the stand-alone platform.

The final integration step concerned the integration of the different simulators (LATCH, ATS, and the A-SMGCS simulator). This step concerned the technical interfacing with the DIS protocol and the facilitation of the simulators with Heathrow and Schiphol databases. Major effort has been put into the creation of 3D visual databases for LATCH and ATS and in the creation of a pseudo pilot station for ATS.

The eventual semantic integration of the platforms was left for the simulation phase of the project. During the validation in WP4000, the correct functioning of tools and correct connections between tools and simulators (like co-ordinate systems) has been tested extensively.

The integration process has been visualized in figure 6.

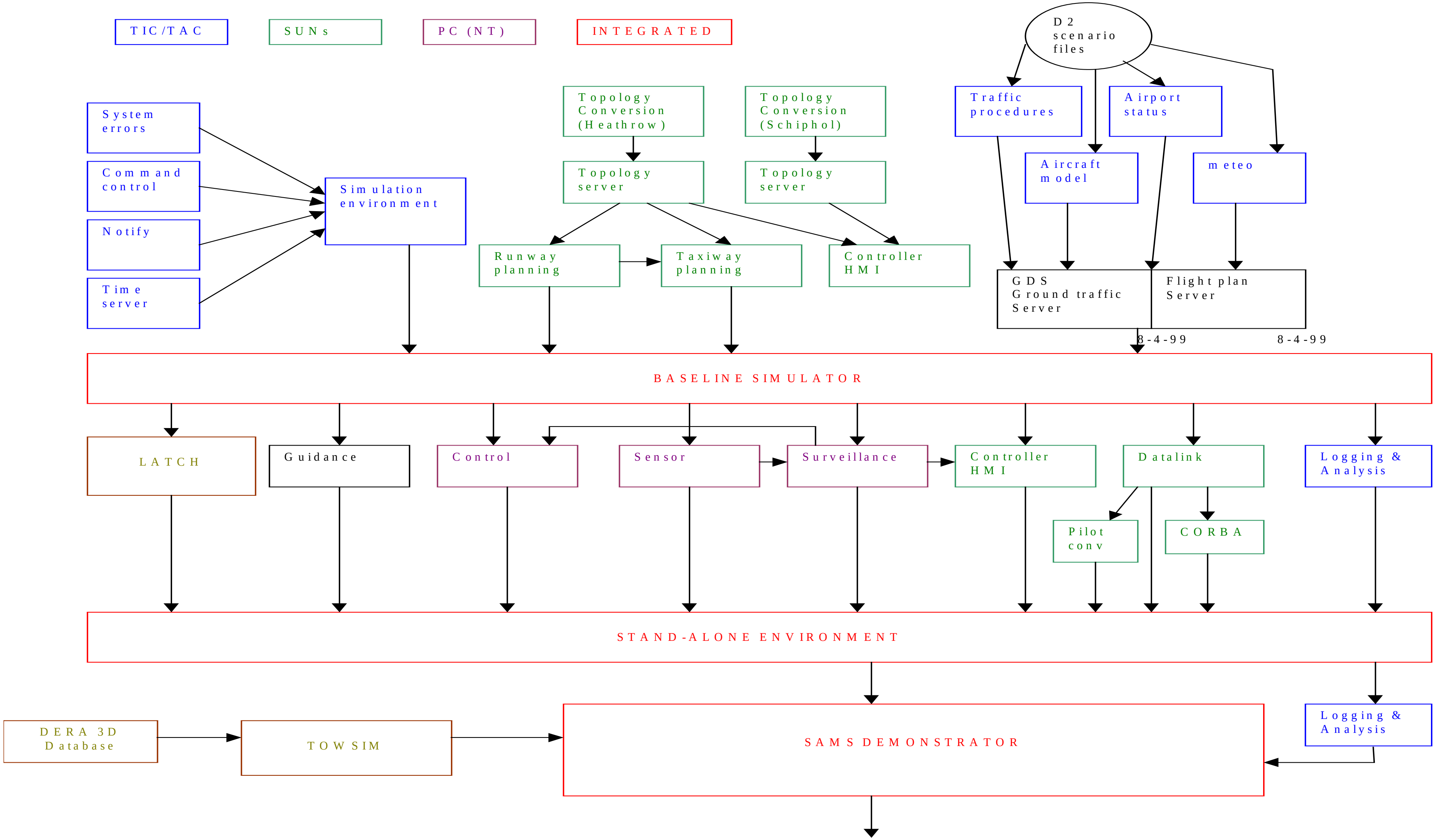

Figure 6, SAMS Integration process.

)

3.3.2. Acceptance procedures

To ease integration of the different servers, an incremental acceptance procedure has been used. This procedure consists of five consecutive steps. Depending on the availability of tools and support software, per server it will be indicated which steps have to be taken, see also table 1.

The five steps are:

1. Test the tool at the developer's site without its CORBA interfaces. This is a functional black box test demonstrating the proper function of the whole tool. This test may consist of running several scenarios. This is NOT the developer's test to see if the internal functions are correctly invoked, if loops are correct, etc. if step 2 proves proper functioning of the tool, this first step of the acceptance procedure can be omitted. The choice for step 1 or 2 depends on the availability of a CORBA implementation at the developer’s site.

2. Test the tool at the developer's site with its CORBA interface. This again is a functional black box test, now with CORBA drivers to produce input for the tool from a scenario file and CORBA stubs to accept output from the tool.

3. Test the tool at NLR with its CORBA interface, in the same environment as in step 2. This can be regarded as a "delivery"-test. The scenario of step 2 is repeated at the target site. This purpose of this test is to demonstrate appropriate behaviour and to test environment issues like version of the operating system, libraries, etc.

4. Test the tool, separately, in the SAMS environment. Now, the scenario that was used in step 3 is used and the drivers are replaced by the real SAMS tools (for as far as possible). During this test, the LAN (Local Area Network) can be used and correct library functions can be used. Further, the tools that have been integrated in the MANTEA environment are taken out and put in the SAMS environment.

5. Test the tool at NLR in the complete SAMS environment. Here the co-operation between tools is tested. An integrated scenario will be used, based on the individual test scenarios from step 4.

Table 1 shows the extent to which all tools will be tested. Step 3 and 5 are required. Step 4 is highly recommended, especially for the tools that have been pre-integrated in the MANTEA environment, but can sometimes not be performed since several basic tools are needed first. Step 1 can be omitted if step 2 is in place (depending on the availability of CORBA at the developer's site).

Server	Step 1	Step 2	Step 3	Step 4	Step 5
	Module tests			Integration tests	
Supervisor	x	x	x	x	x
Time		x	x	x	x
Error		x	x	x	x
Meteo		x	x	x	x
Flight plan	x	x	x	x	x
Aircraft model		x	x	x	x
Traffic procedures		x	x	x	x
Sensor		x	x	x	x
Surveillance		x	x	x	x

Control		x	x	x	x
Controller HMI		x	x		x
Pilot HMI	x		n/a	n/a	n/a
Topology		x	x		x
Taxiway Planning		x	x		x
Runway Planning		x	x		x
Guidance		x	x		x
Datalink	x	x	x	x	x
Logging & Analysis		x	x	x	x

Table 1, software integration test steps.

3.3.3. Integration details

During the integration work, an on-line Interface Control Document was kept up-to-date. The objective of this document was to specify the detailed design of the interfaces between the various modules (H/W and S/W) of which the SAMS platform consisted. The interfaces were described using the Interface Definition Language (IDL), which allowed the partners to design and develop their components independently and still enabled a consistent design of the platform.

The Interface Definition Language (IDL) was used to describe the interface of objects in Orbix. An interface definition provides all of the information needed to develop clients that use the interface. An interface typically specifies the attributes and operations belonging to that interface as well as the parameters of each operation. From the IDL descriptions, C++ code was generated that could be connected to the existing software, enabling the software to communicate with other servers without knowing details of the other servers, nor of the communication protocol. Defining the interfaces of the various modules of the SAMS platform in IDL enabled the partners to develop their contribution separately from one another with a consistent design as result.

The remainder of this section will detail a number of the integration aspects.

3.3.3.1. Subscription and notification service

The subscription service has been developed by ISR.

In a client-server architecture, an object in a server has two ways of providing services to a client object:

- either the client (actively) executes a method on the server object (e.g. execution of a get_xxx() function) (synchronous communication),
- or, the client first subscribes to the server and then waits till the server calls a method on the client when specific events occur (asynchronous communication).

The implementation of the get-mechanism is straightforward. To obtain quickly all the relevant information, the most important classes will provide a get_value function, which will return a structure of type XxxValue where Xxx is the name of the class. Only the second way of obtaining services is of interest in this section. The CORBA implementation used (Orbix from IONA Technologies) did not provide a default mechanism for subscribing, so the SAMS project had to define the mechanism themselves. This mechanism is also called “publish and subscribe”.

The two important aspects in this type of communication are that:

- the client must call a method on the server to subscribe (i.e. check in) and eventually later, call another method on the server to cancel the subscription (i.e. check out),
- once the clients have subscribed, the server must call methods on the clients (i.e. notify the clients); to perform those calls, the server must know the methods' signatures which it must call on each of its clients.

Concerning the subscription by the client to the server, it is important to note that polymorphism of methods does not exist in IDL. To register clients of N different types, the server must offer 2xN different methods (i.e. one to check in + one to check out for each type of client) except if all the clients share a common super-class.

The limitation of number of method declarations on the server to implement the subscription mechanisms (aspect 1) can be obtained by the definition of a *Notified* class. All clients wanting to subscribe to a server should inherit from the Notified class and call the *check_in* and *check_out* methods on the server.

Concerning the notification of the server to the clients, it is useful that, for a given event, the signature of the methods called by the server on the clients is similar on all clients. This can be obtained by the definition of a *XxxSubscriber* class where Xxx is the name of the server. All clients wanting to subscribe to a server Xxx should inherit from the XxxSubscriber class.

The ServerSubscriber class declares[1] all the services provided by the server through the subscription mechanism. All clients wishing to make use of those services should simply inherit from that class and define the use they want to make of the methods triggered by the server.

```
oneway[2] void consider_conflictCreated(
                        in Conflict aConflict,
                        in ConflictValue aCnflctVal);
oneway void consider_conflictUpdated(
                        in Conflict aConflict);
oneway void consider_conflictDeleted(
                        in ConflictValue aCnflctVal);
```

All clients wanting to subscribe to conflict creations, updates and deletions should inherit from the ConflictSubscriber class (and, through it, from the Notified class). They should then define the way they want use the events when the ConflictFactory server automatically triggers the methods (see figure 7).

---

[1] It is only a declaration (i.e. not a definition) to state the signature of the methods. If this concept existed in IDL, it would be similar to the virtual methods of C++.

[2] Asynchronous: could be suppressed if the server requires a confirmation that its message has been received.

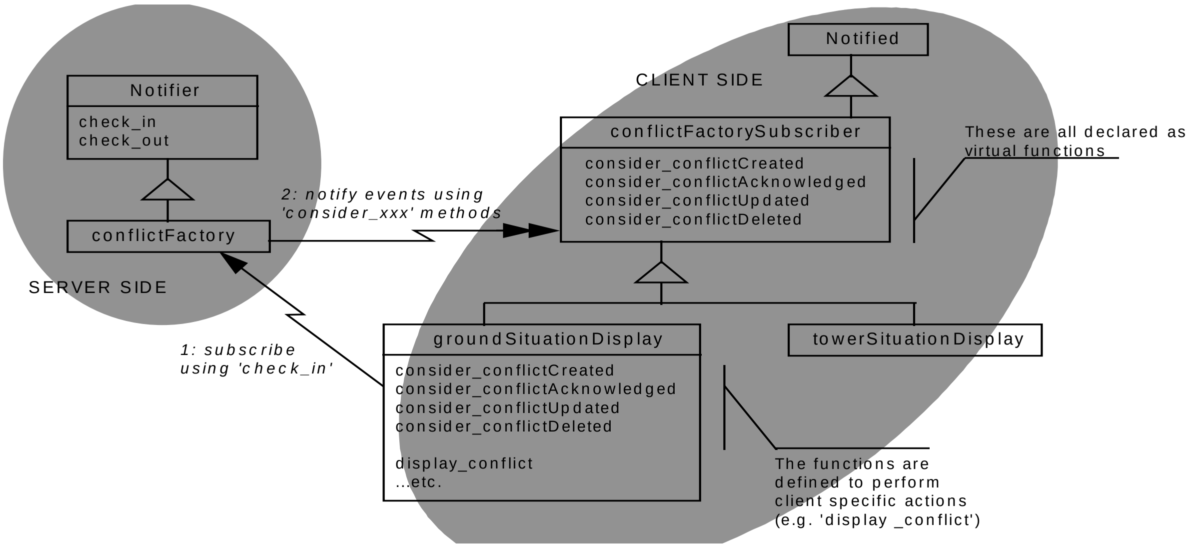

Figure 7, Example of object structure and main method calls.

3.3.3.2. Simulation management service

The simulation management service has been developed by NLR.

In a distributed system, it is important that one of the servers is responsible for starting and stopping the simulation process. For SAMS, it was chosen to use the SMARTFED tool as a basis. SMARTFED had been developed for communications of clients and servers in a DIS or HLA environment and therefore was adapted to be able to communication over CORBA middleware.

Every server has to register with the simulation manager. With this registration, the server will provide its name and the hostname of the machine it is running on. From then on, the simulation manager will be able to start up the different servers. The simulation management file, which is the configuration file of the simulation and an input file for the simulation manager, contains the names of all servers and corresponding hostnames[3] of the machines that participate in one specific simulation.

Next the *"Start Connect"* command can be issued. After reception of this command, each server establishes the connections with other servers, which it needs to communicate with. The "Start Connect" phase is finished once all servers have sent a response to the simulation manager. After this the *"Initialise"* command may be issued. As a result the servers will perform initialisation, such as reading input files. After a successful initialisation, the servers will respond to the simulation manager. Once all servers have initialised, the *"Run"* command can be issued, causing all servers to start with the specified simulation start time. Finally, the simulation can be stopped at all times by issuing the *"Stop"* command.

Figure 8 shows the above-described process.

---

[3] In fact, a bug in the Orbix implementation made it necessary to specify the IP-address in stead of the hostname.

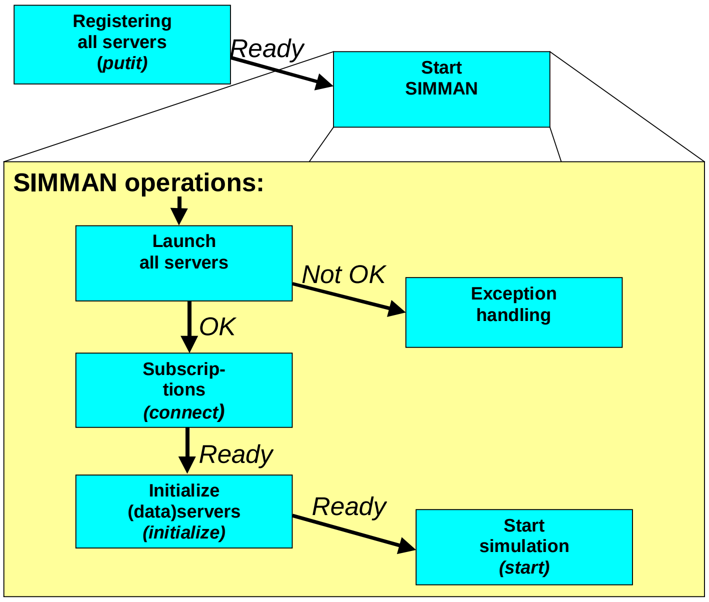

Figure 8, Simulation manager process.

The simulation manager could have been integrated with the time server (e.g. for giving the current clock time or for giving signals at predefined intervals). However, in SAMS, it has been decided that every server would have to take care of time management itself. The only time management performed in the simulation manager server is the synchronisation of the simulation start time. The clock time of the simulation was passed to the servers with the *"initialise"* command.

3.3.3.3. Co-ordinate translations

The use of different simulators and different pre-built servers, as well as the use of different communication protocols, made it necessary to convert co-ordinate systems.

Both the LATCH and the A-SMGCS used a vector-space (x,y,z relative to a point of reference). However they used different points of reference and different directions for the x-, y- and z-axis. Their points of reference were located on the surface of the earth, the x- and y-axis along the surface of the earth, and the z-axis perpendicular to the surface. To complicate things further the x- and y-axis of the LATCH and the A-SMGCS were swapped and the z-axis inverted.

The DIS protocol internally also uses a vector-space. However it uses the centre of the earth as its point of reference, the x- and y-axis in the plane of the equator, and the z-axis through the North Pole. The VR-Link DIS tool we used provided functions for the conversion between the two co-ordinate systems. Since DLR (ATS) did not have this tool they had to implement the conversion functions themselves.

One additional consideration was that not only position of the aircraft, but also heading and speed and for the visuals systems also yaw, pitch, and roll needed to be converted into all formats. The DIS protocol needs the speed and heading information to calculate the position of the aircraft in between receiving position data samples.

3.3.3.4. Interface descriptions

Reference 10 gives a detailed description of the interfaces between the SAMS functions. The document has been maintained during the life cycle of the project and frozen at the start of the integration process. Minor modifications have been carried out in the interfaces between the functions, which had to be communicated between the partners involved. The latest version of the document was always available via an on-line ftp-site for SAMS at NLR.

The interfaces in Ref. 10 are set up in a functional design with each SAMS function being a process description. The interfaces have been described using the Interface Definition Language (IDL), which allowed the partners to design and develop their components independently and still enabled a consistent design of the platform. Standard design and naming conventions have been prescribed.

Once the interfaces were described in IDL, software could be generated from it using the Orbix implementation of CORBA. IDL is a C++-like language that can directly be understood by the CORBA implementation used. From the IDL descriptions, C++ code was generated that could be connected to the existing software, enabling the software to communicate with other servers without knowing details of the other servers, nor of the communication protocol.

The architecture proposed makes it possible to incrementally build a complete A-SMGCS simulation. New functions can easily be added to an existing platform. An additional benefit of this approach is that existing functions are easily replaced by enhanced ones. The proposed architecture also enables an incremental integration of the platform.

3.3.3.5. Use of DIS

The DIS protocol was used for communications between the LATCH (DERA), A-SMGCS (NLR) and ATS (DLR). Two dedicated ISDN lines were used for the DIS data, one from NLR to DERA and one from NLR to DLR.

The DIS data was broadcasted over the SAMS network at NLR and the SAMS network at DERA. At DLR there was no separate SAMS network in place therefor a filter was installed at NLR to translate broadcasted DIS traffic to unicast traffic to the DLR, and to translate unicast DIS messages from DLR to broadcast DIS messages at NLR and DERA. Although the DIS data could be received by all SAMS servers at NLR, only the TIC server used the data. The TIC server functioned as a translator between DIS and CORBA messages.

The data communicated consisted of the following types: *Aircraft state vectors*, *Simulation timing information*, *Uplink and Downlink messages*, *Reduced traffic information* and *Topology information*. Figure 9 shows the different communications that were exchanged between the different SAMS sites.

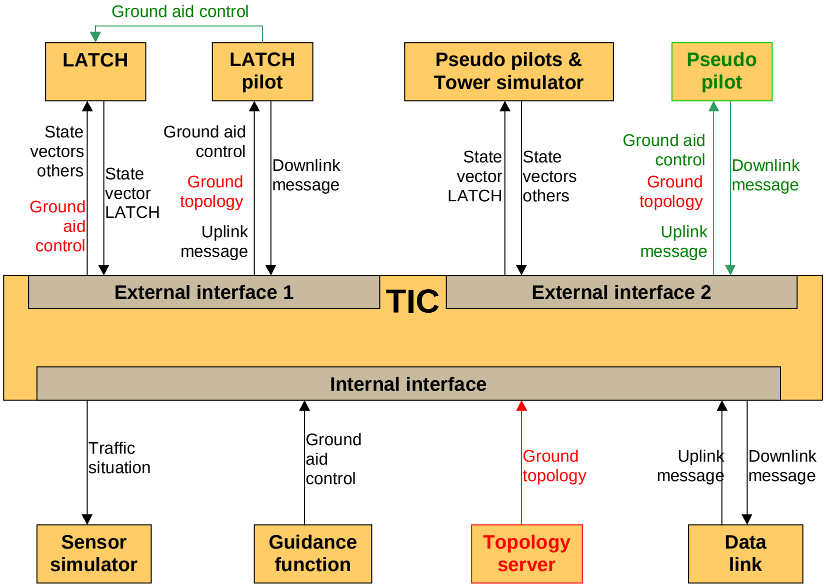

Figure 9, Interfaces that communicate via DIS.

LATCH and ATS generated the *Aircraft state vectors*, the information was on the other end for the visual display of the external aircraft, and by TIC to be translated to CORBA as input for the Sensor server.

The TIC server generated the *Simulation timing information*. This information is a direct translation of the information given by the Simulation manager about the initialisation, begin, and end of the simulation.

The *Uplink and Downlink messages* consisted of clearance information.

The *reduced traffic situation* communicated to LATCH explored the possibility to let pilots have a view of the traffic in its direct surroundings, thereby removing the limitation of the visual view from the cockpit windows.

The *topology information* communicated to the LATCH gave the pilot information of the airport topology and the route the aircraft should follow.

3.3.3.6. Pseudo pilot station design

In order to be able to use ATS, it was necessary to develop pseudo pilot stations for the airports to be simulated: Schiphol and Heathrow. A variety of editing tools was used for the preparation of the experiments. Flight plan and procedure editors were used to schedule the behaviour of each aircraft, including its parking position, pushback and taxi procedure, and the preferred runway and departure or arrival route. A map editor was used to generate the airport model. Below, the different editing tools are briefly described.

Map editor:

The lay out of the airport must be shown to the pseudo pilots. For this, a map editor is available. Depiction of the airport to the pseudo pilots is an optimisation problem: on the one hand, it is only used for position information, on the other hand, pilots must recognise positions at the airport. The simplest way to achieve the airport lay out is by using a bit map and draw the lines that depict taxiways, runways, and aprons over it.

Secondly, the map editor must be used to define relevant points at the airport. These are all decision points, like crossings, position of the runway, corners in taxiways, gates, etc. These points must then be connected via lines over which the aircraft will be depicted during taxiing.

The map editor concludes with a static description of the airport.

Airdes (airport designer):

The airdes tool gives dynamic to the objects that have been entered in the map editor. This means that names, parking directions at gates, speeds on taxiways and runways, mandatory stopping points, etc. will be entered. Each point will be designed as a member of a certain object type, like "runway", "taxiway", "terminal", "nav point", "centreline", or "borders of grass/concrete". Some of the objects must be given attributes, like runway hold point, runway landing point, etc.

A second use of the airdes tool is to design routes over the airport. Routes enable pseudo pilots to select one of the available routes from a list and so speed up the entry process per aircraft. If no routes are entered, pseudo pilots must select (with a mouse) all decision points that an aircraft must taxi over one by one. Considering the fact, that at Heathrow and Schiphol, one taxi route consists of about twenty points, the benefit of using routes (which can be handled by one mouse click) is clear.

Entering routes in airdes is a two-step process. Firstly, legs are defined. Legs are sequences of points and as such, part of routes. Since the development of routes was a huge job, for SAMS it was decided to mainly use legs. Both the airports of Heathrow and Schiphol have a similar configuration of runways, taxiways, and aprons. The basic concept is that most aprons are positioned in the centre of the airport, around which two circles of taxiways are laid. The runways are positioned at the outer part of the airport around the circle of taxiways. These taxiway circles were divided into halve circles to form legs as such. Then, from all aprons to the circle and from all runways to the circles, legs were designed. In this way, major part of the routes could be entered by the pseudo pilots with only three mouse clicks. For example, an aircraft that just landed needs one entry from the pseudo pilot for the leg between the runway and the circle, one for the direction in which the circle will be used (left or right turn) and one for the final part from the circle to the gate.

Finally, legs and routes can have attributes. These had to be entered in airdes as well. Attributes are for example: "stop distance before a given point", "parking directions", "turn radius between two legs (default = 50 meter)", "mark runway exits/entries", and “push-back procedures”.

3.4. WP4000: VALIDATION AND DEMONSTRATION

Objective of the work package “Validation and Demonstration” was to describe and approach for and to validate the overall SAMS platform and to perform two full scale demonstrations for operational airport sites (Schiphol and Heathrow). Demonstration results have been analysed in this work package.

The Validation Plan and Scenario document (ref. 5) describes the actions to be undertaken to show and demonstrate that SAMS is an A-SMGCS real-time man-in-the-loop integration platform for the Schiphol and Heathrow environments. From the user requirements, the experiments have been defined as required to demonstrate that the SAMS platform is capable of realistically simulating the actual and future ATC/A-SMGCS functions described.

Two experiments were considered, one for Schiphol and one for Heathrow, each demonstrating functions defined for the respective airports. They have been elaborated to demonstrate that the SAMS platform would be capable of:

- Providing a faithful reproduction of ATC operations.
- Realistically testing of new ATC functions.
- Evaluating the benefits of these new procedures by end-users (such as controllers, pilots, air traffic service providers, airport authorities, and aviation authorities).

The validation tests described in reference 5 are based on the operational concepts outlined in reference 4 (SAMS Operational Concept) and reference. 7 (Functional Specifications Document). Reference has also been made to test scripts - these are detailed instructions to pseudo pilots and pilots for the performance of man-in-the-loop trials. The relationship of this document with the other data required for the demonstration is shown in the diagram x.

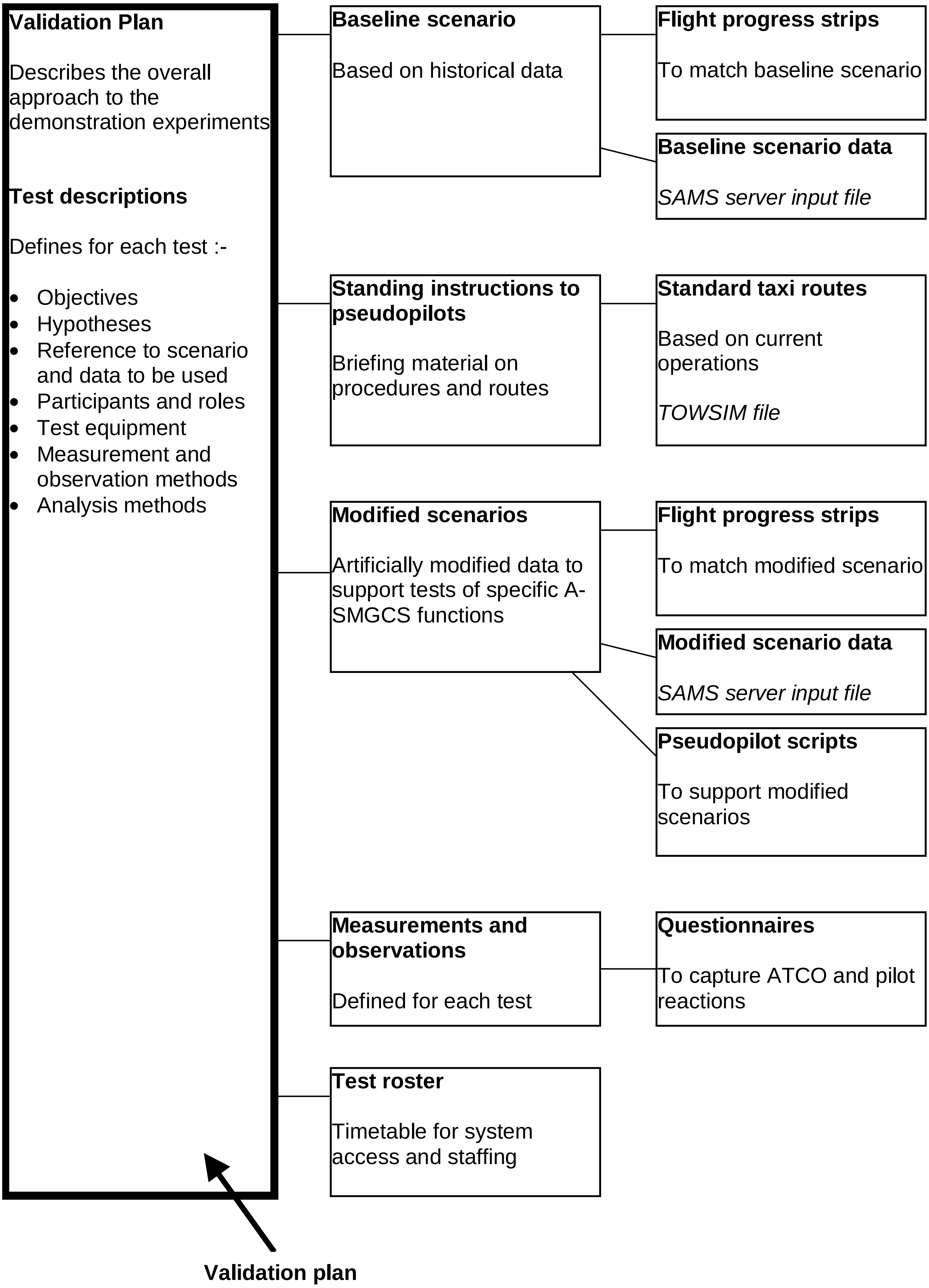

Diagram x. Relationship of the validation plan to other SAMS documents and to detailed notes.

3.4.1. Validation overview

Two experiments have been performed, one for Schiphol airport and one for Heathrow. Schiphol Tower Control simulations focussed on labelling and runway incursion alert. Heathrow took the labelled display further (with status indicators and a pending arrivals window) and added planning/routing and taxiway conflict alert to the experiment. In the context of Heathrow, use of guidance and data link had been planned to be examined, however, the functions proved not ready in time, so that only limited effort was spend to validating those functions.

The approach taken in validation was an integral approach. The complete set of A-SMGCS was simulated during the validation, while the emphasis of the successive validation experiments was on a limited set of aspects (like labelling). The operational procedures, as far as relevant, for each airport were followed as closely as possible. Although limited, the users did get time for training on the simulator and for getting familiar with the use of the A-SMGCS features.

The validation consisted of three phases:

- *SAMS Platform Validation*. The Platform Validation validated, from a users viewpoint, the applicability of the SAMS platform to host, interface, and connect existing and future A-SMGCS functions. The purpose of the platform validation test was to confirm correct operation of the integrated platform before a full scenario simulation would be set up. Controllers and pilots were invited into the facilities. During this time, operators were trained in the use of the system and the systems functions were evaluated against the requirements specified in D1 SAMS Operational Concept (Ref. 4).

- *SAMS Basic Validation*. The Basic Validation concerned the simulation of the existing situation at Schiphol and Heathrow. The Air Traffic Controller had to judge the realism of the SAMS simulations without any new SMGCS addition. These scenarios have been called Basic Scenarios. The Basic Validations will established a degree of realism of the SAMS simulations for Schiphol and Heathrow. The controller’s responses have been captured by questionnaires.

- *SAMS Added Functions Validation*. The Added Functions Validation validated the use of the SAMS platform when adding A-SMGCS functions. The user was asked to conclude on operational use and integration of A-SMGCS as simulated in SAMS. This validation concerned the actual SAMS functions and will be elaborated in the next section.

3.4.2. Added functions validation

In order to demonstrate and validate the SAMS platform, two added functions have been tested for Schiphol: labelling and runway incursion alert. For Heathrow, six added functions were planned to be tested with controllers: labelling, runway incursion alert, taxiway conflict alert, A-SMGCS data link, taxiway planning, runway planning, and guidance. Validation goals and objectives are given below.

3.4.2.1. Labelling

An advanced function, providing additional information in the form of a label, will enhance the situational awareness of the controllers and possibly the safety and efficiency of the traffic flows on the airport. The label corresponding to a certain vehicle or aircraft is attached to the corresponding radar track update with a leader line. Supplementary information as well as the information contained in the label is also displayed on the SAMS equivalent of the Electronic Data Display (EDD). A survey of the responsibilities and tasks of controllers in the airport tower is presented in SAMS Deliverable D1 (Ref. 4).

The controller is able to control the information visible in the label by selecting call sign only or full labels.

The heading of the aircraft is represented by use of an aircraft symbol and a speed vector instead of the more usual plots. This speed vector predicts where the aircraft will be in the next few seconds.

Note: The research objectives 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 safety and efficiency of the traffic flows on the airport. This should especially be true for adverse visual conditions. Specifically for Heathrow, a more efficient taxiway/stop bar selection may be possible if ATC can maintain situational awareness in all traffic conditions, which may provide the ability to fractionally increase ground movement capacity in LVPs, which may permit for example greater numbers of towing movements.

During the SAMS validation, three situations have been simulated:

- HMI without labels (present day situation),
- HMI with 100% reliable labels and
- HMI with realistic label drop.

3.4.2.2. Runway Incursion Alert

Reference 11 describes the validation of the control function in detail.

The Runway Incursion Alert (RIA) serves as an extra safety measure on an airport. The RIA function works in the background (“watchdog” function) and only shows its presence in the case of an incursion. An incursion may be defined as a situation in which an object (vehicle or aircraft) enters a restricted area (e.g. the protection zone around an active runway) without specific permission to do so. If this happens, intervention of the controller is required to prevent possible disasters. The controllers are however very busy, therefore an automatic function which detects incursions and alerts the controllers to a potential hazardous situation would be an improvement to the overall safety of the airport. This is especially the case during low visibility conditions in which the controllers have difficulty seeing and identifying all the traffic on the airport. Since control over the departing flights is transferred to the tower controller from the ground controller (vice versa for arrivals) at the runway holding position, confusion related to the transfer of control is an additional possibility for runway incursions.

To prevent aircraft and vehicles from entering restricted areas, two zones were defined in SAMS around restricted areas (e.g. an active runway) for the RIA function (see figure 10); a yellow safety area and a red restricted area. This enables a warning signal to be triggered before an actual RIA occurs, possibly requiring a rejected take off or go around.

If a vehicle or an aircraft would enter the yellow area (the Runway Protection Zone (RPZ) as defined by e.g. the FAA), a pre-alarm was triggered. The controller and the driver of the intruding vehicle or aircraft were notified. Without the yellow warning phase, it is supposed that an alarm would always be too late to prevent an actual incursion. The rules for runway incursion are summarised in Annex III.

The red zone is the actual restricted area, where no traffic is allowed to enter, without specific permission of the tower controller in charge of the runway. The borders of this area coincide e.g. with the location of the stop bars. At this point control of traffic is usually transferred from the ground controller to the tower controller (departures) or vice versa (arrivals). Taxiing aircraft or vehicles, which only need to cross the runway, will have to obtain permission from the tower control of the specific runway before entering the red area.

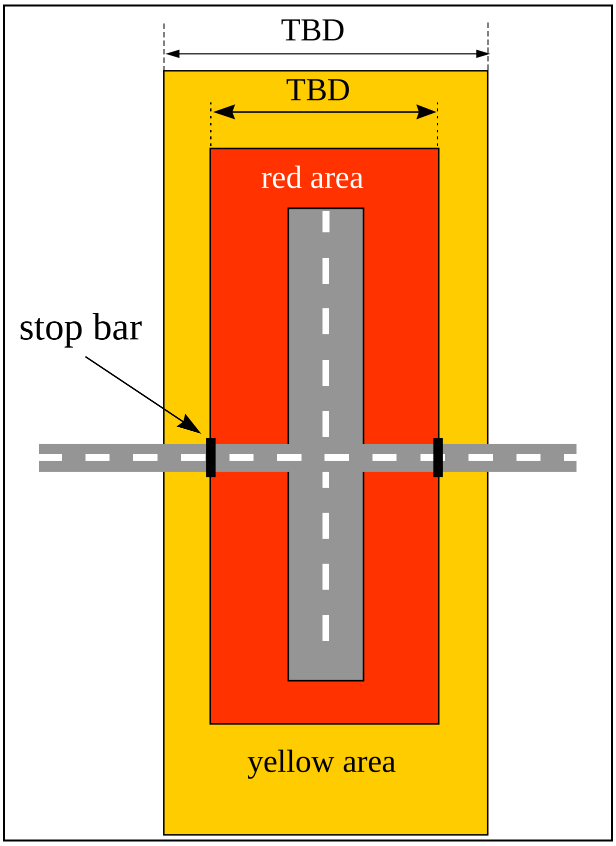

Figure 10, RIA alert areas.

During the SAMS validations, provisions were made to test several sizes of the yellow warning and red alarm areas.

Objectives were to determine the optimal size of the yellow and red RIA areas and to get an impression about the control and system reaction times involved. Furthermore, the time parameters for the control rules of RIA should be determined. Finally, the possibility of leaving the controller out of the loop (use audio warning in LATCH cockpit) has been investigated.

The hypothesis to be validated was that a conflict alert function would increase safety margins and during low visibility operations controllers would be able to maintain situational awareness without recourse to aircraft position reports, thereby reducing frequency loading. SAMS would address the first hypothesis in a demonstration simulation.

3.4.2.3. Taxiway Conflict Alert

These functions are defined in references 11 and 13.

Hypothesis to be validated was that conflict alert would increase safety margins and during low visibility operations controllers would be able to maintain situational awareness without recourse to aircraft position reports, thereby reducing frequency loading. SAMS addressed the safety margin hypothesis in a demonstration simulation, which repeatedly tested a specific taxiway conflict alert rule.

3.4.2.4. A-SMGCS Data Link

Aim of the data link validation was to demonstrate that would possible to evaluate the benefit of a controller to pilot data link using the SAMS simulator

The hypothesis to be validated was that data link for clearance delivery would reduce ground movement planner workload. Data link for clearance delivery would reduce ground movement controller workload. This demonstration attempted to show that the second of these hypotheses could be evaluated in simulation.

The tests were defined to concentrate on demonstrating the functionality of this sub-system, with qualitative feedback from controllers only.

3.4.2.5. Taxiway Planning

The aim of validating the taxiway planning function was to demonstrate that it was possible to evaluate the benefit of a planning function to support ground movement control, using the SAMS simulator.

The hypothesis to be validated was that a taxiway planning function would reduce the workload of the ground movement controller and would allow a smoother traffic flow over the airport. It would also enable controllers to better anticipate to aircraft movements, hence reducing taxiing and holding times.

3.4.2.6. Runway Planning and Sequencing

The requirements for this function are described in <Ref 1>.

The aim of validating the runway planning function was to demonstrate that was possible to evaluate the benefits of a planning and sequencing tool using the SAMS simulator.

The hypothesis to be validated was that a runway planning function would reduce controller work load and would allow the ground movement controller to give push back and taxi clearances closer to the anticipated departure time, hence reducing time spent taxiing and holding at the runway hold area and reducing the queue length at the runway hold area.

3.4.2.7. Guidance

The aim of validating the guidance function was to demonstrate that was possible to evaluate the benefit of a guidance system using the SAMS simulator. The tests concentrated on demonstrating the functionality of this sub-system, with qualitative feedback from controllers only.

The hypothesis to be validated was that automatic guidance could safely be used as a replacement for the manual system whilst still maintaining flow rate at the present level (current system has night-time flow rate comparable to the rate during daylight hours).

3.4.3. Data logging

Although the SAMS demonstration tests were not intended to gather statistically valid samples of data, it was a requirement to demonstrate that data could be logged and retrieved for analysis. This is a key function for quantitative evaluations of tools, as it makes it possible for statistics to be collected over numerous simulated aircraft movements. Questionnaires were used for qualitative analysis:

- Questionnaire about the level of realism of the SAMS simulation environment.
- Questionnaire about workload
- Questionnaire about perceived safety margin
- Questionnaire about impact of nuisance alerts.
- Pilot questionnaire

The ATS and LATCH facilities allow for many parameters to be logged automatically. A video recorder was used to record the situation in the tower, the cockpit, and the A-SMGCS HMI.

The A-SMGCS simulator provided logging possibilities in two different ways. Firstly, the different individual servers were capable of producing log-files. After each run of the simulators, the log-files were collected and saved in a specific directory. Secondly, a specific CORBA-server has been constructed that logged many events during the simulation. This server just connected to the A-SMGCS servers in order to make it possible to evaluate the order in which the A-SGMCS events took place during a simulation. The latter was necessary e.g. to identify *which* track update eventually caused a conflict to occur, hence to correlate the data from different servers. By examining the different log files from the surveillance and control modules, it was not possible to exactly identify the event that caused the conflict.

A useful logging function was that provided by the TIC-server. This server logged the incoming DIS-messages from ATS and LATCH. A special reader has been developed that takes the (modified) TIC log-file as input and produces track messages as if they were coming from ATS and LATCH. This feature enabled the possibilities of off-line testing the A-SMGCS platform, once simulation runs with the ATS and/or LATCH were performed.

3.4.4. Scenarios used

For each type of experiment, a number of scenarios needed to be prepared. They will be detailed below.

3.4.4.1. Labelling scenarios

Three situations have been modelled:

- No Labelling (which is the same as the existing situation).
- Perfect Labelling.
- Realistic Labelling (with specified label drop).

The validation criterion focussed on the usability of computer generated labels. After familiarisation on the first Schiphol demonstration day, labelling was studied in a progressive manner. First the situation for 100 % reliable labels was compared to the no-labelling situation. Then realistic labelling was compared to the no-label and perfect label situation.

3.4.4.2. Runway incursion scenarios

Scenarios have been build with one or more runways in use, and taxiing or crossing traffic, causing infringements to the protected zones at unpredictable moments. In other trials aircraft did not vacate the runway in time, forcing landing aircraft eventually to a rejected take-off or a landing abort and go-around. This demonstration focussed on the question whether SAMS would be capable of researching concepts to alert controllers and/or pilots.

Two aspects of runway incursions were examined, see also Annex III. The research on geometric aspects is called Basic Runway Incursion Alert (BRIA), the research dealing with both geometric and dynamic aspect of runway incursion is called Advanced Runway Incursion Alert (ARIA).

BRIA allows detection of a target entering the yellow and/or the red area across a runway. BRIA gives a warning or alarm independent of a landing or starting aircraft on the same runway. BRIA thus studied the usefulness of area infringement only.

ARIA adds conditions for landing and starting aircraft on the same runway to the BRIA. ARIA studied the following concept:

- Runway conflict alert when an arriving aircraft is T1 seconds or less from the runway threshold and another target is entering the yellow area in Low Visibility.
- Runway conflict alert when an arriving aircraft is T2 seconds or less from the runway threshold and another target is entering the yellow area in Good Visibility.

- Runway conflict alert when an arriving aircraft is T3 seconds or less from the runway threshold and another target is entering the red area in Low Visibility.
- Runway conflict alert when an arriving aircraft is T4 seconds or less from the runway threshold and another target is entering the red area in Good Visibility.

3.4.4.3. Taxiway Collision Alert scenarios

Taxiway Collision Alert was only validated for Heathrow. The following scenario was proposed:

Busy traffic scenario (landings of 27L), with taxiway conflict modification as follows - a selected aircraft of type B747 will be cleared to land and will vacate at block 79, 102 or 100 (this aircraft will be controlled by means of the DERA B747 cockpit simulator). On contact with ground movement control, they will be cleared to taxi towards the east along the outer taxiway. Another aircraft (controlled by a pseudo-pilot) will land and be instructed to hold at the 81/104(o) stop bar (normal co-ordination between ground movement control and air arrivals controllers will be deliberately omitted at this point). A conflict will occur when the first aircraft approaches block 60(o) from block 104(o).

3.4.4.4. Data link scenarios

Data link was only validated for Heathrow. For the validation of the data link function, it was necessary that both ATS and LATCH participated in the exercises. The following busy traffic scenario was proposed:

Clearances must be given to departing and arriving aircraft via a silent data link. Data link equipped traffic will be controlled by means of the DERA B747 cockpit simulator. A distribution of time on frequency per movement would be calculated. A comparison could then be made of the on-frequency time with data link equipped and non data link equipped aircraft.

In SAMS, the data link function has been validated to a limited extend.

3.4.4.5. Taxiway Planning scenarios

Taxiway planning was only validated for Heathrow. A busy scenario was proposed.

The time between start of taxi and departure and the time between taking a runway exit and arriving at a stand can be measured. The distribution in times can be compared with a baseline distribution.

In SAMS, the taxiway planning function was validated to a limited extend.

3.4.4.6. Runway Planning and Sequencing scenarios

Runway planning was only validated for Heathrow. A busy scenario was proposed.

The time between start of taxi and departure for each aircraft can be measured and the distribution calculated. Then, a comparison of the distribution for planning-aided traffic with baseline distribution could be made.

In SAMS, the runway planning and sequencing function has not been validated, because of integration problems with the function.

3.4.4.7. Guidance scenarios

The SAMS guidance function was only validated for Heathrow. A busy traffic scenario was proposed, where both ATS and LATCH were involved.

In the scenario, the LATCH B747 cockpit would be used to control a number of landings and taxi in manoeuvres. The exercise must be situated in night-time under good visibility conditions. The time between aircraft controlled by means of the LATCH cockpit vacating the runway and arrival on stand can be measured. The distribution for automatically guided traffic with daytime baseline can be calculated.

In SAMS, the guidance function has not been validated, because of integration problems.

3.5. SIMULATIONS SET UP

The SAMS project has delivered a real time simulation platform for integration testing of existing and future Advanced Surface Movement Guidance and Control System (A-SMGCS) functions. The emphasis in the SAMS platform is on real time man-in-the-loop simulations.

During the SAMS demonstration, several observers have been following the simulations. Questionnaires were used, focusing on the usability of the labels and their impact on workload, safety and efficiency of airport ground operations.

Two simulation sessions have been conducted to assess the A-SMGCS functionality within the SAMS platform.

The first session lasted for two weeks. A first week was dedicated for Schiphol demonstrations, for which two controllers were available from 15 to 19 November 1999. During a second demonstration week, two Heathrow controllers were available from 24 to 26 November 1999.

An additional simulation period was scheduled with Heathrow controllers between 20th – 23rd of December. 1999 Feedback obtained during the November simulations had been taken into account and modifications and enhancements had been made to the SAMS platform and associated functions. The December simulation was focused upon establishing a baseline that was acceptable to the Heathrow controllers.

The evaluation undertaken in December resulted in further feedback from the controllers and enabled technical issues to be addressed concerning some of the SAMS functions. The technical work undertaken on the SAMS functions, notably the runway incursion alert function was completed by January enabling the hand-over of the SAMS platform to the ATOPS project.

This section describes the main results of the SAMS project and reports upon the technical analysis of the simulations. A detailed report can be found in Ref. 14.

3.5.1. *Simulation objectives*

The SAMS simulation platform was developed to support future A-SMGCS activities with the aim of evaluating the operational benefits that could be foreseen at various airports in ground traffic management through the implementation of the A-SMGCS functions.

The SAMS project goal was to design and develop a real-time, man-in-the-loop platform capable of testing and demonstrating new support tools and/or new A-SMGCS procedures in all weather conditions.

The aim of the SAMS simulations was to prove the capability of the SAMS platform using its various components to provide a representative simulation environment to support the evaluation of the ASMGCS benefits in the context of two major airports: London Heathrow and Amsterdam Airport Schiphol. These simulations, which are outlined below, are a part of the overall validation plan (Ref. 5).

3.5.1.1. Schiphol simulation

The aim of the simulations was to prove the platform capability as a test platform for surveillance and control functions.

The objectives of the Schiphol simulations were:

- The evaluation of SAMS as a platform providing A-SMGCS functions, focussing on labelled Surveillance and Runway Incursion Alert (RIA) functions, integrated into present day operations.
- The reproduction of a realistic man-in-the-loop simulation of present day Schiphol Tower and Ground Control.
- To familiarise project members with the ATS facility.
- To familiarise project members with the SAMS platform.
- To study labelling (100% labels and less reliable).
- To examine controller and pilot responses to runway incursion alert.

3.5.1.2. Heathrow simulation

A baseline for the simulation was established by conducting a scenario known as the SAMS Basic Validation for Heathrow. This scenario simulated the present day situation at London Heathrow on the SAMS platform. Once controllers become familiar with the environment they were asked to provide feedback on the realism of the simulation. The scenario was also used to provide a small baseline data sample of simulated ATC performance in both good visibility and LVP conditions. This sample was used for comparison against data obtained from the added function tests.

Once a baseline was established, additional scenarios were run to assess three Added Functions. These functions are Labelled Surveillance, Runway Conflict Alert, Taxiway Conflict Alert, Runway Planning, Data link, and Guidance. An additional function, Runway Planning, was also planned to be tested but there was insufficient time available to undertake an Initial Test.

3.5.2. Scenarios

It had been planned to simulate three variations of the baseline scenario so as to obtain data for the three different baselines, namely good daylight visibility conditions, low daylight visibility conditions, and good night-time visibility conditions. However, due to time constraints and technical limitations, it was decided not to simulate night-time good visibility conditions. Consequently, two baseline scenarios were used: good visibility daylight conditions and low visibility daylight conditions.

The following points were investigated during the evaluation scenarios:

- Adaptability of the platform to various contexts.
- Co-ordination of the various sites during simulation runs.
- Technical and practical availability of the platform.
- Flexibility in the loading of operational scenarios.

The aircraft in the simulation were controlled by either the pseudo-pilots or the B747 simulator pilot. The pseudo-pilots used an ATS PC-interface to control several aircraft at the same time. The pseudo-pilots also controlled ground vehicles by means of the same PC-interface. The B747 simulator pilot was in control of one aircraft using an actual B747 cockpit

3.5.2.1. Schiphol

3.5.2.1.1.Participants

Two operational Schiphol tower controllers took part in the evaluation activities during the first week (15th – 19th November 1999). The two controllers assumed the roles of Tower or Ground Controller. One of the participating controllers is a currently validated Schiphol controller and is involved in the implementation of A-SMGCS at Schiphol airport. The other controller used to be an active controller at Schiphol, but is now retired. He was also involved in the production of the European A-SMGCS Manual. Both controllers also have radar control experience from TMA and En-route traffic control.

Up to four pseudo-pilots, supplied by NLR, NATS, and Delair ATS, were used during the Schiphol simulations. One pseudo pilot has a commercial pilot license. The DERA Bedford B747 Cockpit Simulator was controlled by either technical staff or a commercial licensed pilot.

On 23rd December 1999, a one-day session was held with one controller. This was part of the second SAMS demonstration period. One of the controllers that was available during the first period also participated in this second session.

3.5.2.1.2.Meteorological Conditions

The meteorological parameters were amended manually so as to correspond with the runway use and the information displayed on the controller HMI.

The visibility settings of the Tower Visual Simulator were analysed by the controllers as depicted in table 2.

Tower Visual Simulator value	Compared to Schiphol reality	Simulation Category
100 m	less than 400 m	Low
6 km	about 2 km	Medium
200 km	better than 10 km	Good

Table 2, ATS visibility settings.

3.5.2.1.3.Traffic Sample

Three types of scenarios, as defined in SAMS validation plan (Ref. 5) were supplied:

- Familiarisation scenarios.
- Advanced Surveillance scenarios.
- Runway Incursion scenarios.

Familiarisation scenarios were aimed at training controllers and pilots on the SAMS simulation facilities, while enabling the tuning of simulation parameters. The simulation parameters were set as close as possible (controller’s judgement) to the reality at Schiphol airport. They resulted in the right traffic intensities in terms of low-medium - busy for a two-controller tower and in the right visibility settings as seen from the tower.

Advanced Surveillance scenarios were selected to study the use of labelled radar surveillance with varying visibility and traffic density. Perfect labelling was compared with situations without labels or with intermediate quality labels. Runway incursions were enforced on the last day of the Schiphol demonstration to test incursion settings and acceptance by the controllers.

SAMS Schiphol demonstrations were based on recorded flight plans from Schiphol airport from a week in July 1999. An analysis was made of runway use and inbound and outbound traffic intensity per hour. Subsets of about one hour were selected with the desired runway combinations and traffic intensities. Additional processing was needed to restrict company and aircraft types to combinations supported by the DLR tower simulator. If changes in aircraft type or airline were needed, effort was paid to give preference to the airlines that frequently visit Schiphol airport. When controllers got familiar with the traffic sample, another subset was taken from the available collection.

The traffic intensity definitions for the two controller Schiphol demonstrations were found to be as depicted in table 3.

Low traffic	about 20 aircraft moving per hour
Medium traffic	about 40 aircraft moving per hour
Busy traffic	up to 80 aircraft moving per hour

Table 3, Traffic intensity for Schiphol.

3.5.2.1.4.Schiphol Airport Layout

A stand-alone airport chart was available for reference at the pseudo and simulator pilot positions.

3.5.2.1.4.1.Runways in Use

The runways in use were determined prior to the start of the simulation. It has been decided that the following runways (see table 4) must be used for all of the scenarios:

01R, 06, 19R, 24	Arrivals
01L, 09, 19L, 24	Departures

Table 4, Runways in use for Schiphol.

3.5.2.1.5.Operating Procedures

The procedures used during the simulations reflected current control procedures for traffic at Schiphol airport as closely as possible. Schiphol uses stand or gate numbers, inner and outer track with one-way preferences, and designations for apron entry and runway exit. Apron control is carried out by the Ground controller. Runway crossings require co-ordination between Tower and Ground controller. Further details on the operational concept can be found in SAMS operational concept and functional specifications (Ref. 4).

3.5.2.2. Heathrow

3.5.2.2.1.Participants

Two operational Heathrow tower controllers took part in the validation activity during the second week (22nd – 26th November 1999) of the first period (last three days) and during the second period (21st – 23rd December 1999). The same controllers participated in both periods, so that their experiences from the first period could be reused and a new training and familiarisation session was not necessary for the second period.

Three controller positions were simulated during the baseline validation. The positions of Air Arrivals, Air Departures and Ground Movement Controller were manned. The operational controllers manned the Air Departures and Ground Movement Controller positions. A member of the NATS SAMS team manned the Air Arrivals position.

The pseudo-pilots participated in the baseline scenarios. The DERA B747 simulator was not used for the baseline scenarios, but participated in the advanced scenarios.

3.5.2.2.2.Meteorological Conditions

Both good and low visibility meteorological conditions during the hours of daylight were used for this scenario.

The good visibility parameters were set so that the visibility was in excess of 10 km, cloud cover consisted of broken, high level cloud, and there was no significant weather within the visual range of the tower.

The meteorological conditions for the Low Visibility Procedures (LVP) scenario were set so that:

a) The Instantaneous Runway Visual Range (IRVR) was less than 600 metres, or

b) The cloud ceiling was 200 feet or less above aerodrome level.

3.5.2.2.3.Traffic Sample

Two traffic samples available were used to establish a baseline. The samples were based upon real data collected from Heathrow and contained:

- A busy sample, to represent good visibility daylight operations.
- A traffic sample suited to Low Visibility Procedures.

Both traffic samples were used for the validation testing and simulations. Table 5 provides the details of the samples used.

Sample	Time of Day	Visibility	Time of Sample	Date of Sample
1	Daytime	Good	0600 – 0800 UTC	04-06-99
2	Daytime	Low	0600 – 0800 UTC	04-06-99

Table 5, Heathrow traffic samples.

3.5.2.2.4.Heathrow Airport Layout

A stand-alone airport chart was available for reference at the pseudo and simulator pilot positions.

3.5.2.2.4.1.Runways in Use

The runways in use were determined prior to the start of the simulation. It was decided that the runways would be used for all of the scenarios, as given in table 6.

27L	Arrivals
27R	Departures

Table 6, Runways in use for Heathrow.

3.5.2.2.5.Operating Procedures

All manoeuvres conducted by aircraft and vehicles under the control of the pseudo / simulator pilots were done in accordance with instructions received from Air Traffic Control. Exceptions to this were (i) specified in the Scenario Specific Procedures provided to the pseudo-pilots or (ii) unless instructed otherwise by the simulation supervisor for the purpose of investigating specific SAMS functionality, e.g. for runway incursion alerts.

When the ground control position was manned for the simulation exercise, the controller issued taxi instructions to aircraft and vehicles under his responsibility, i.e. on the manoeuvring area. The taxi instructions specified the route to be followed in order to proceed from the runway entry / exit point to the stand and vice-versa. Taxi instructions were also issued to aircraft under tow and ground vehicles proceeding from one part of the airport to another.

When the ground control position was not manned for an exercise, the pseudo-pilots taxied their aircraft to the holding point of runway 27R (for departures) or to the designated stand (for arrivals) by the most direct route. However, aircraft did not enter or cross either of the active runways, namely 27L and 27R, without first obtaining the authorisation of the appropriate tower controller.

The Arrival controller was responsible for aircraft and vehicles wishing to enter/cross runway 27L.

The Departure controller was responsible for aircraft and vehicles wishing to enter/cross runway 27R.

Low Visibility Procedures (LVP) were implemented for the Heathrow simulations.

4. CONCLUSIONS

This chapter will describe the results of the simulations that have been described in section 3.5 It will detail the different sessions that took place during the demonstration periods and will give potential benefits and proposals for further work.

4.1. TECHNICAL AND OPERATIONAL RESULTS ACHIEVED

This section gives a description of the simulations that have been performed and details the results that have been achieved during the different sessions.

4.1.1. *Scenarios performed*

This sections gives a day by day objective description of the simulations. The Schiphol simulations detailed below were conducted from 15th till 19th November and on 21st December 1999. The Heathrow simulations were conducted from 22nd to 26th November and from 22nd to 24th December 1999. In the following sections, the observations from the SAMS observers, controllers, and pilots will be detailed. A video camera was used to monitor the activities of the controllers and observe the actions they took on the SAMS HMI.

The SAMS Schiphol demonstration that took place from November 15th till 19th 1999 suffered from incompletely tested A-SMGCS software. The simulations were accomplished with an unstable system. However, it was decided not to postpone the simulations, but to use the available time slot in ATS for the Schiphol demonstration parallel with continued integration testing.

Several engineering tests were conducted throughout the week commencing 22nd November 1999. The first two days of the week (22 / 23 November) were used to explore the implemented functionality. Situations were set up using the DERA Bedford B747 simulator and pseudo-piloted aircraft to test runway incursion alert and to examine the performance of the controller HMI, with particular emphasis on the labelled Surface Movement Radar (SMR). From the third day on, controllers participated.

The additional simulations conducted between 20th to 23rd December enabled further investigation of the runway incursion alert function for Schiphol and Heathrow. The feedback provided by the controllers and observers enabled modifications to be made to the conflict alert function.

Day 1 (15 November 1999): Schiphol training and familiarisation. A number of runs was performed in order to familiarise participants with the system. The ATS and LATCH facilities operated well; the SAMS A-SMGCS platform was available, but not yet complete and consequently was not used intensively. The participating controllers and pilot confirmed that the system resembles Schiphol well enough to continue the SAMS trials. Some parts of the 3D visuals, namely the areas around the gates (some aircraft are parked inside the buildings) and the inner track in between L10 and L12, required updating.

Day 2 (16 November 1999): Schiphol labelling. A variety of tests were performed with little success. Only when a clear start-up sequence for all simulators was implemented did the system became on-line for more than a few minutes at the time. A number of successful short runs was conducted at the end of the day. These runs consisted of good visibility scenarios. The purpose of the runs was to evaluate the scenarios used with the controllers in order to find the most suitable traffic samples.

Day 3 (17 November 1999): Schiphol labelling. A number of tests on labelling were performed with considerable success. However numerous crashes in the SAMS platform occurred. The crashes were in the HMI, surveillance, TIC, and ATS components. On most occasions, it was possible to continue the exercise and restart the SAMS platform during the run, while controllers continued their work without the A-SMGCS part of the system. However, the restart process took 2-3 minutes. Both good and low visibility scenarios were used.

Day 4 (18 November 1999): Schiphol labelling. The crash rate decreased due to adjustments made on the A-SMGCS simulator and ATS. However, the HMI and surveillance functions were still unstable. A quicker restart procedure was discovered by reducing the numbers of active servers and hence functionality.

A number of tests were conducted with the Bedford B747 simulator to determine the number of aircraft which could be seen on the B747's visual system, the relative positions of those aircraft, and the positions of runways, taxiways and buildings compared to the positions as depicted on the controller HMI. It is understood that the B747's visual system supports the display of up to eight. The pilot converter, to reduce the aircraft that are sent to LATCH to eight aircraft, still needed to be installed.

The controllers were observed to become more familiar with the system and were noted to be using the facilities of the HMI. This day marked the start of performance measuring for the evaluation of the SAMS platform.

Day 5 (19 November 1999): Schiphol labelling and runway incursion alert. Unfortunately, an ISDN problem during the course of the day caused a considerable delay. A few runway incursions were observed at the beginning of the exercise, but before real tests could be started the system stopped detecting runway incursions. Technical improvements in the inter-site communication gave a smoother appearance of the aircraft on both LATCH and ATS. Further evaluation measurements were taken.

Conclusion Day 1 – 5: First Schiphol trials: Despite some shortcoming it was possible to obtain results and to reach the goals of the Schiphol demonstrations:

- To reproduce a realistic man-in-the-loop simulation of today Schiphol tower operations
- To evaluate SAMS as a platform for testing and integration of A-SMGCS components, with emphasis on labelling and runway incursion alert.

Day 6 (22 November 1999): Heathrow baseline test. No controllers participated. A number of runs was performed to familiarise the Heathrow controllers with the system. Some modifications to the visuals were made during the day. A simplification that was made in the conversion of ATS information to DIS-format caused problems with the control function. Control gave a lot of erroneous messages, caused by wrong speed information of the ATS generated aircraft. A modification to LATCH was made to enable use the head-down display.

The surveillance and control functions were more stable than the week before, resulting in some successful test with the A-SMGCS simulator system.

Day 7 (23 November 1999): Heathrow baseline test. This day was a continuation of the previous day, with emphasis on a baseline test with high controller workload. This merely resulted in a too high workload for the pseudo pilots. The maximum number of aircraft that could be handled by the pseudo pilots appears to be about ten. Baseline tests were set up for both daylight good visibility and daylight low visibility conditions

Day 8 (24 November 1999): Heathrow labelling and runway incursion alert. This was the first day controllers from Heathrow attended the demonstration. The day was mainly used for familiarisation. All traffic was displayed, including aircraft that were waiting at the stands. Controllers argued that there was too much inactive traffic at the SAMS HMI.

A simplification to the ATS pseudo pilot stations (the absence of routes) caused an increased workload for the pseudo pilots.

Day 9 (25 November 1999): Heathrow labelling and runway incursion alert. This day was planned as visitor's day. Observers from AENA, SOFREAVIA, STNA, and NLR visited.

Initially, there were crashes of the system, mainly in the surveillance function, so that it was not running for more than ten consecutive minutes. In the afternoon, two successful sessions were held which made it possible to record a baseline scenario in good visibility conditions. The baseline concern labelled surveillance and control.

Also, a new procedure was tested, where LATCH followed preceding aircraft in low visibility conditions based on visual separation of LATCH only.

The distance-to-touchdown-indicator did not work properly, yet

Day 10 (26 November 1999): Heathrow labelling and runway incursion alert. Another baseline in good visibility conditions could be established with tests for labelled surveillance and control.

A system stress test was performed with over 60 aircraft on the visuals and the HMI (N.B. not all moving at the same moment, but they were existent in the system and shown on the visuals and the HMI). The ATS visuals became a little slow and the pseudo pilots (four at that time) were not able to cope with the traffic load. Controllers however, indicated that the load for them was not yet at a maximum.

Conclusion Day 6 – 10: First Heathrow trials: It was not possible to test the scenarios focused upon taxiway alerts, datalink, runway planning / sequencing and guidance as the functionality required for these scenarios had not been fully implemented. The validation of these functions was delayed until the second demonstration period.

Like for the Schiphol demonstration, the objectives were reached to reproduce a realistic man-in-the-loop simulation of today Heathrow tower operations with the remark that controllers found the workload not yet enough. The major shortcoming appeared the number of pseudo pilots, not the technical achievements of the system. For the second demonstration period, more pseudo pilots were asked. The SAMS platform was considered a good platform for evaluating and testing of A-SMGCS components, with emphasis on labelling and runway incursion alert.

Day 11 (20 December 1999): Engineering tests for Heathrow and Schiphol. Additional facilities for the debriefing and videotaping of the exercises were installed during software runs. The download and installation of the SAMS HMI to the SUN workstations took about one hour to complete. Some problems with the ISDN line (unrecognised data packages) were solved. DERA had amended the visual system so as to display the eight aircraft closest in terms of relative position to the LATCH simulator. This worked properly.

Several runway incursion scenarios were run and evaluated. In general, the majority of the conflict warnings popped up at the correct moment, however, some conflicts were missed or appeared at a wrong moment.

The stability of the A-SMGCS functions has increased significantly since the previous simulation period.

Day 12 (21 December 1999): Heathrow baseline tests. LATCH was not involved in this exercise.

The tests were extended to facilitate positions for three controllers (ground movement, air departures, and air arrivals) and six pseudo-pilots (push-back & taxi out, vacate runway & taxi in, towing, departures-1, departures-2, and arrivals). It was believed that the system was being pushed to its limits. Each run lasted about 45 minutes, after which the scenarios reached their end. Controllers felt that the traffic volume was sufficient compared to a busy day at Heathrow, and the complexity of the traffic was adequate. This scenario was accepted as a good baseline trial.

The tests included use of the labelled surveillance function and the HMI. Initially, controllers used the configuration as is for Heathrow, i.e. no labels on the ground radar position and labels on the terminal approach radar, which is zoomed out so that it shows airborne arrivals and departures only. Later, controllers used the HMI more extensively with full labels and more HMI functions (like zoom and the second display).

Day 13 (22 December 1999): Engineering tests. A test was performed to check the performance of the system. A visual observation of one taxiing aircraft showed no significant delay, although during the arrival at the runway (at high speed), it looked like some delay occurred in the system. A larger sample showed a delay in arrivals of about three seconds, however, controllers did not find this a major concern. The ISDN capacity between NLR and DLR appeared to be the limiting factor. Using two or more lines could easily have enhanced the data capacity, but would have increased costs and, more important, the necessary infrastructure in the simulation rooms would have to be extended.

The advanced functions for taxiway planning, deviation monitoring, and datalink (reduced uplink and downlink) were tested. Controllers had the possibility to interact with the planning display. Although the planning function was technically operational, heavy traffic scenarios overloaded the computing system, so that a real-time evaluation of the taxiway planning function was not possible.

A facility for communicating with LATCH on the same channel as the pseudo-pilots has been installed. External communication is going over a phone line between DERA and DLR before the LATCH R/T is interlinked with the R/T from the pseudo-pilots. Voice communication between ATS controllers and LATCH pilot was of low volume, so that in some occasions clearances and requests could not be understood.

Day 14 (23 December 1999): Schiphol tests for labelled surveillance and control. One Schiphol controller participated.

The test with a stream of arrival traffic was performed to check if the control function was operating. Numerous conflicts were generated on purpose and corresponding conflicts were shown on the HMI. Some measurements were taken to check the validity of the conflicts. Some conflicts appeared to occur at exactly the correct moment, however, some conflicts showed too late.

Another test was performed to check different sensor qualities. Label drop probability of 1 did not show any labels, which is a correct observation. Label drop probability 0 correctly shows all active labels. A modification to the HMI made it possible to remove labels from the display.

Evaluations with the electronic strip bays were made. The controller mainly commented on the order in which the strips were sorted.

Conclusion from the second simulation period: The engineering test has been finished and succeeded. The baseline test proved that a sufficient amount of traffic could be handled by the system. Controllers felt that the traffic volume was sufficient compared to busy days and the complexity of the traffic was adequate.

Major improvements were made to increase the stability of the platform. Considering the short period of time and the numerous functions that had to be tested, no measured validation could be performed. This task will mainly be performed in the ATOPS project.

4.1.2. *Feedback from end users*

In this section, comments from the controllers and pilots are gathered. Since they were asked to comment “as much as possible” and the system was only operational for the first time, there were numerous observations. The comments are ordered in comments on the realism of the traffic samples, general comments on the A-SMGCS platform, general pseudo pilots comments, comments on ATS, and comments from the LATCH crew.

4.1.2.1. Traffic Samples

The controllers found the Low Visibility Procedures traffic sample to be consistent with the recommended LVP traffic loading at Heathrow. The controllers suggested that a Lighting Operator position be incorporated into the simulation so as to increase the level of realism.

The controllers stated that about 30% of the workload at Heathrow relates to aircraft being towed from the stands to parking positions and vice-versa. They were of the opinion that the realism of the simulation would be increased if towing activity was included in future exercises.

The controllers commented that ‘work in progress’ often affects day-to-day operations at Heathrow. Such work can include repairs to taxiways, which mean aircraft having to be routed via alternative taxiways. This leads to an increase in workload, which may account for another 10% increase in workload.

The controllers stated that the change in aircraft type, livery and/or call sign required for the simulated traffic samples due to the constraints of the visual system caused some confusion and were a distraction. The visual system does not contain all the liveries for all the aircraft that were in the original traffic sample collected at Heathrow. It therefore became necessary to modify call signs in the original traffic sample to fit with the aircraft type in the external visuals. For example, BAW8T, a Boeing 747, was changed to be DLH8T for the simulation, as the external visuals did not support a B747 in British Airways colours. Such changes impacted upon the controllers’ workload as the controllers learn which call signs relate to specific gates. The changes to the call signs led to some instances of call sign confusion and instances of aircraft initially being sent to the incorrect stand.

The feedback provided by the Heathrow controllers during the November simulation enabled modifications to be made to the traffic sample and to the pseudo-pilot configuration. These adjustments, which included the introduction of towing movements, resulted in a higher, more realistic, workload being achieved during the December simulations. The controllers participating in the December simulation noted that the throughput of aircraft, especially on the departure position, had been improved and the traffic sample was acceptable as a baseline for good visibility daylight operations.

4.1.2.2. Miscellaneous

The controllers recommended that an Aerodrome Traffic Monitor (ATM) be incorporated into the system. The ATM is used at Heathrow to monitor departing aircraft as well as arriving aircraft. The Departures controller uses the ATM to ensure that the aircraft have started the turn published in the applicable SID prior to clearing the subsequent aircraft to take-off.

During the November simulations the controllers recommended that the traffic samples be adapted so as to start with some aircraft already at the holding point for the departure runway. This would replicate a more realistic situation at the start of a simulation. The traffic samples were modified prior to the December simulation so that some aircraft were pre-positioned at the holding point at the start of the exercises. This modification assisted in creating a more realistic traffic flow and thereby gaining controller approval for a good visibility daylight baseline sample.

The controllers suggested that a number of taxiway routes are pre-defined for the simulation. This would alleviate the workload on the pseudo-pilots manning the “ground movement control”-pilot positions. The controllers provided details of which taxiways are used on a standard basis. Following the conclusion of the November simulation, a few pre-defined taxi routes were implemented on the SAMS platform. The implementation of these taxi routes enabled the pseudo-pilots to select a pre-defined route rather than having to create a route by clicking on the nodes on the HMI. The availability of pre-defined taxi routes reduced the pseudo-pilot workload in the December simulation and consequently assisted in increasing the throughput of traffic, which resulted in a good visibility daylight baseline being achieved.

4.1.2.3. Pseudo pilot Feedback

The pseudo-pilots commented that during the Heathrow simulations the work for the pseudo-pilot responsible for the departures, i.e. the outbound traffic, was approaching the limit of what could be handled. The short term solution was the addition of another pseudo-pilot to assist in the handling of the departing traffic.

4.1.2.4. ATS analysis

4.1.2.4.1.Visuals

The 300° projection system was able to provide acceptable simulated outside views of Heathrow and Schiphol. The Schiphol controllers commented that the visuals required adjusting for the gates and parking positions. The portrayal of the runways and taxiways did not present problems to the Amsterdam controllers.

The Heathrow controllers proposed several changes to the layout of the external visuals. The eye height of the controller working positions was adjusted to a more realistic value (approx. 35m) which, in the opinion of the participating controllers, gave a better perspective of the airport. A number of improvements and slight changes to the external visuals were made on a daily basis as the week progressed.

The Heathrow controllers commented that the aircraft at the holding points for runway 27R seemed to lack definition when compared to aircraft at the holding points for runway 27L. It was determined that the aircraft at the hold for runway 27R appeared to be tail-on to the controllers, whereas in reality they would not be tail-on. This resulted in the aircraft at the 27R hold taking up less pixels on the visual display than aircraft at the 27L hold. As the definition of the aircraft on the visual system is better at the 27L hold, it was decided to swap the arrival and departure runways for the ATOPS simulations. Runway 27R would be the arrivals runway for ATOPS with 27L being used for departures. The majority of the comments was on the quality of the databases, supplied by SAMS and gradually improved by the SAMS partner responsible.

The colours, textures, projection and perspective, light conditions, and clouds were all of sufficient quality to run the SAMS demonstrations. The set of available aircraft liveries was restricting for the Dutch and English simulations (see

Heathrow Controller comments). Care was taken during the preparation to give preference to the companies and aircraft types frequently seen at Schiphol and Heathrow.

4.1.2.4.2.Pseudo pilot station

Inexperienced pseudo pilots need about three or four days full simulation for training. The station itself has many possibilities to control the aircraft, however, it takes some time to find out how to operate the station. Some problems were caused by the way the stations were prepared for the Schiphol and Heathrow demonstrations. Other problems stemmed from bugs in the (licensed) software. The feature to distribute the control of aircraft among an arbitrary workstation turned out to be very useful in the event of a particular station crashing.

4.1.2.4.3.Controller working positions

The SAMS project provided two radar displays and two data displays for the simulation. These were mounted instead of the DLR workstations in the controller desks in the tower simulator. There was enough space for a three-controller set up, as used during the Heathrow simulation.

4.1.2.4.4.Interfacing

Problems were found connecting the tower simulator via ISDN to the SAMS platform in Amsterdam. SAMS asked for the DIS protocol, but, for understandable reasons, DLR could not supply the DIS protocol. Programming was therefore needed by DLR to emulate DIS. A solution was reached for the start of the demonstrations. However, during the simulations the interfacing proved to be unstable and further improvements were required. A fix was created and maintained, that enabled demonstrations of more than 30 minutes to be run, which was sufficient for the intended evaluations. The interface between the tower simulator in one building and the pseudo pilot stations in the other building at the DLR Braunschweig site worked well.

4.1.2.4.5.Preparation

For each airport it took approximately 6 man weeks of engineering effort to create maps, routes, procedures, and to test and validate the work. Use was made of leased software, belonging to the tower simulator. The learning time proved to be longer than expected and some bugs in the editing software delayed the progress. The co-operation of DLR and the supplier of the software ensured that the problems were minimised enabling preparations to be completed in time for the reserved simulation periods. Changes and improvements during the simulations were implemented between the sessions.

4.1.2.4.6.Command and control

It was determined that the correct procedure to start the multi-site simulation was to give the start lead to the tower simulator operator. The tower simulator started the session by building up the outside views and static traffic. A voice message was then given to the SAMS platform operator in Amsterdam and the B747 operator at DERA Bedford to join the simulation. Once the controller HMI was initialised, voice co-ordination was done to advise the pseudo pilots to start moving. During the run, the simulation co-ordinator in the tower simulator was in command.

During the December sessions, an internet chat-box was set up to overcome the open telephone line for the voice communications between the sites. The chat was joined by the ATS operator, in another building than the actual simulator, so that four sites were connected. No delay on the internet network was found, so that the simulation times in all simulators were running with accurately synchronous time.

4.1.2.4.7.Recording

No use was made of the DLR recording facilities. SAMS provided its own recording of data records in Amsterdam and recorded video images of the controller HMI. DLR supplied extra cabling to put an additional monitor in the tower facility for use by observers and to assist with video recording.

4.1.2.4.8.Platform flexibility

The flexibility of the SAMS platform was observed throughout the three weeks of simulation. The platform was readily able to switch between the Schiphol and Heathrow environments. During a demonstration day (23rd November 1999), ATS was loaded with the new Frankfurt airport visual file to exhibit the detailed visual display. This impromptu switch demonstrated the flexibility of the ATS facility. In addition to the visual context file that needs to be produced for a new airport, the new airport layout information, and the relevant traffic scenario need to be input into the traffic generation function that is a part of the control tower visual simulator environment (ATS). The configuration of the SAMS platform was demonstrated as being flexible and this aspect of the SAMS platform is considered to be suitable for further utilisation.

4.1.2.5. Feedback from LATCH Crew

4.1.2.5.1.Aircraft Model

The LATCH aircraft model has the following perceived deficiencies (from a commercial pilot’s point of view) with respect to takeoff and flying capabilities:

- The aircraft model is very sensitive in pitch and roll.
- The rudder is very sensitive on takeoff.

Putting the above comments in context: The LATCH aircraft model is a generic large civil aircraft; as such it is not representative (in terms of handling qualities) of any particular commercial aircraft, e.g. it handles more responsively than a 747 would. The current model could be modified to improve its handling performance, or a different civil aircraft model could be integrated into the LATCH system.

4.1.2.5.2.Cockpit Instrumentation

The commercial pilot who took part in the SAMS trials preferred to have the electronic trim switch mounted on the control column. LATCH is easily reconfigured to mount the trim switch on either the P1 or P2 control column, or the central console.

To fly the LATCH aircraft properly, an engine instrumentation display would be required. Such a display was produced for the SAMS trials but not used. Minimum effort would be required to integrate the display for subsequent trials.

The commercial pilot who took part in the SAMS trials was unfamiliar with the pitch bars and flight path vector shown on the Primary Flight Display (PFD). A dot in the middle of the two pitch bars would have improved the usability of the PFD.

For effective taxiing and landing approaches, ground speed should be shown on the PFD.

The moving map display (onboard guidance HDD) was well received by the pilot but with the following suggestions for improvement:

- A hardcopy airport map would still be required because the moving map does not display holding points, gate numbers, and links.

- A vector on the moving map display indicating airport heading would be useful when the airport map is off screen.

- The moving map display is excessively cluttered with 30-40 other aircraft displayed.

4.1.2.5.3.Cockpit Communications

The commercial pilot who took part in the SAMS trials would have preferred push-to-talk on the headset microphone.

The sound quality of the communications between the LATCH cockpit headsets and the ATS Control Tower, via a telephone link, was very poor.

4.1.2.5.4.Cockpit Controls

The LATCH cockpit controls performed as specified.

4.1.2.5.5.Out-of-Cockpit Visuals

Severe problems were encountered with the stability of the out-of-cockpit visuals.

Initial problems were encountered with scene overload due to the complexity of the visual database models used to display external aircraft (generated by pseudo-pilots at DLR). These problems were resolved by simplifying the visual database models.

Further problems were encountered after the filter to dynamically change the eight aircraft on view was implemented (changing the list of aircraft and corresponding visual database models at runtime caused the visual system to crash). These problems were resolved by mapping all external aircraft to the same visual database model (B747).

There were anomalies in the movement and attitude of the external aircraft on the out-of-cockpit visuals (low frequency jitter and a “bank” angle for aircraft on the ground). It is suspected that these anomalies are due to incorrect handling of DIS dead-reckoning information and/or geocentric co-ordinates, but further investigation would be required to prove this and resolve the anomalies.

4.1.2.5.6.Moving Map HDD

The Moving Map HDD performed as specified, with the exception that guidance information (taxiway plans, datalink messages and the status of stop bars) could not be displayed because the functionality to provide this information was not implemented in the SAMS platform.

4.1.3. Feedback on the A-SMGCS functions

This section will give controller feedback and technical feedback on the A-SMGCS functions validation. Considering the short demonstration period and the large amount of functions to be tested, and taking into consideration that this was a first trial period, no objective measurements could be taken. The sections will provide a general introduction and detail specific comments from Schiphol and Heathrow trails.

4.1.3.1. Labelled Surveillance function

The capabilities of the surveillance module exhibited during the demos included the presentation of traffic detected by three simulated sensors (Mode-S, DGPS and ASDE). The traffic was depicted both with labels and without labels, depending on the objective of the simulation exercise. Some errors of track position were discovered, which was probably due to communication problems. However, the overall performance of the surveillance function was good, although in the early stages of the simulations, the function lacked stability in technical operation.

Although the simulator is capable of presenting both SSR equipped and non-equipped vehicles and aircraft, there was no opportunity to see any non-equipped traffic. Nor was there an opportunity to test the manual labelling function.

There was no opportunity to switch off any of the simulated sensors to see if the surveillance function performance is degraded accordingly. Such a test would be very useful to explore required changes in procedures depending on the quality factor of the surveillance.

4.1.3.1.1.Schiphol

The evaluation of the use of labelled surveillance with operational controllers was undertaken during the Schiphol simulation week. Controllers stated that the use of labels in low visibility conditions gave them a safer feeling about the traffic. The observation was made that in general, the atmosphere in the tower was calmer with the use of labels. For example, the controllers were focussed on their displays instead of walking around. It would appear that low visibility operations induce less communication in the tower. This is an indication that reliable labelling might reduce R/T loading with a subsequent improvement in capacity.

The surveillance function was found to be lacking in stability during the week of the Schiphol simulations. Greater stability is required in the surveillance component.

Despite the unstable system behaviour, the reaction from both controllers was, ”we should have had this for years”. The operation and use of simulated labelled SMR data with one second updates proved to be acceptable to the controllers, who stated that they did not feel that labelled surveillance impeded workload, capacity or safety.

It was not possible in the Schiphol simulation week to prove other hypotheses from the SAMS validation plan, i.e. “realistic labelling will enhance the situational awareness of controllers, will reduce the controller workload, will enhance the level of safety, will enhance the efficiency”. However, it must be noted that the contrary cannot be deduced either.

4.1.3.1.2.Heathrow

The Labelled Surface Movement Radar (SMR) was, on the whole, working satisfactorily for the purpose of the simulation. The following observations about the labelled SMR were made during the course of the week:

- The controllers stated that for low speed targets the position of the SMR was too accurate and too reliable when compared to the primary radar in use at present. Current systems tend to be less accurate and have targets that fade at certain positions on the airfield.

- The controllers recommended that the labels be deleted for aircraft that have reached their allocated gates. This will reduce the amount of clutter in the areas of the stands / gates. At present, the apron areas become cluttered once the simulation has been running for sufficient time for arriving aircraft to have landed and taxied to their appropriate gates.

- The controllers recommended that a system be implemented to prevent labels from crossing over making it difficult to determine which track the label refers to. A specific example is for aircraft taxiing on runway 23 and the adjacent Inner taxiway. Labels for aircraft on these respective routes had crossed, making it appear that the aircraft actually on runway 23 was on the inner taxiway and vice-versa.

- The baseline Low Visibility Procedures scenario requires the controllers to undertake a simulation without any of the SMGCS functionality. It is therefore a requirement that the controllers can work with only primary Surface Movement Radar, as opposed to a labelled SMR. It should therefore be possible to remove the labels from the SMR to emulate primary radar.

The Distance from Touchdown Indictor (DFTI) is configured to show aircraft landing from left to right regardless of the direction of the runway in use. For the Heathrow validation activity, runway 27L was used for arrivals. Controllers stated that the DFTI presentation should be reversed so as to depict aircraft landing from right to left and thereby correlating the relative aircraft positions with the runway in use. The DFTI alignment issue was implemented after the November simulations enabling the DFTI to be used to monitor approaching aircraft by the controllers in the December evaluation simulations and in the ATOPS simulations.

4.1.3.2. Runway incursion alert / control function

The performance of the control function is directly affected by the surveillance function. There were numerous technical problems with the surveillance function during the simulation and consequently many false Conflict alerts were observed during the runs. In addition some of the rules, such as the Reverse QFU rule, did not work correctly although the runway configuration information appeared to be correct. For instance, alerts were observed for flights undertaking a missed approach and proceeding away from the landing runway, i.e. having gone around.

A good control function is very difficult to achieve, especially in the aerodrome environment, where distances and times are critical. It is impossible to give an assessment of such a function without being able to isolate its effects from the other functions. Consequently the only conclusion that can be reached after studying the documentation is that the function does not currently take into account all of the possible conflicts that may arise during operations in an airport environment. Following further analysis it should be possible to produce additional rules to cover all the required types of conflict. The possibility to inhibit areas for the control function and to inhibit specified rules will assist in the writing of the additional conflict rules.

It was noted that the control function accepts data from different modules of the platform enabling it to be adaptable to changing airport conditions. For instance, due to the interface with the routing function, the conflict function can perform conformance monitoring enabling another route to be calculated in the event that an aircraft is delayed during taxi.

Controller feedback suggested that the pop-up warning messages could be more of a disturbance than an aid. An alternative option would be to present additional information in the track label in case of a conflict warning, thus avoiding the opening of additional windows that need to be closed manually. Additionally, it is suggested that an aural alert be activated as an attention-getting device in the event of a conflict being detected. A further ergonomic problem associated with the pop-up window is that it appears in the same place as other existing windows, e.g. the runway sequences window, and therefore overlays them.

4.1.3.2.1.Schiphol

The control function was only tested very briefly during the Schiphol simulation week.

4.1.3.2.2.Heathrow

The Runway Incursion Alert tool demonstrated some of the required functionality throughout the week of validation activity. However, numerous false alerts were generated during the simulation runs.

The following observations were made during the November simulations with regard to the Runway Incursion Alert function:

- The controllers commented about the large number of alerts, sometimes giving information on less interesting matters like wrong QFU. It was therefore decided to disable some specific advisory messages.

- The runway incursion warning (a *warning* is an alert situation without the potential of real collisions, yet) worked intermittently throughout the validation period. The appropriate warning was observed to be functioning correctly on several occasions, such as two aircraft lining-up on the same runway. However, some potential conflicts were also observed which should have triggered a warning and failed to do so.

- The runway incursion alert appeared to function correctly during the last two days of simulation, following some modifications to the conflict alert module. Conflict alerts were observed for aircraft on short final against aircraft still on the runway.

- The Conflict Alert function was observed to be working when both the runways at Heathrow were configured as departure runways. However, such a configuration also caused false advisories with regard to the incorrect runway being used.

- Aircraft that were positioned downwind, following a missed approach for example, created conflicts against traffic on the nearest runway. Such behaviour was observed on several occasions when the Bedford B747 was downwind. Conflicts were generated against aircraft either on the landing runway (27L) or on the departure runway (27R) depending on the position of the Bedford B747.

- The controllers commented that the pop-up conflict alert window was not required. The highlighting of the position symbols on the Surface Movement Radar was sufficient to indicate the detection of a conflict.

- The controllers were of the opinion that the conflict alert module requires further work and that the parameters need to be experimented with to find the most suitable values.

- The conflict alert function could not detect aircraft that were undertaking a missed approach having been given a ‘go-around’ instruction by the arrivals controller. This means that an aircraft ‘going-around’ continues to be indicated as a conflict against traffic on the runway. The controllers suggested the inclusion of a check to determine if the aircraft is climbing. If an aircraft is climbing then it can be assumed to be ‘going-around’ and the conflict alert cancelled.

- Aircraft crossing the runway behind a landing aircraft generated a warning alert. Controllers stated that this should not happen. Aircraft are frequently given a conditional clearance, e.g. “After the landing British Airways B757, cross Runway 27L”, and consequently cross behind landing traffic.

Modifications were made to the runway incursion alert functionality during the trials and these modifications appear to have resolved some of the erratic behaviour previously observed. However, there were still some issues to be resolved for this function before it can be used with a degree of reliability for future simulations.

Following the completion of the November simulations technical work was undertaken on the runway incursion alert functionality. The software was adapted and tested during the December evaluation simulations. Further feedback was provided by the controllers and observers, which enabled further software modifications to be made.

4.1.3.3. Data link function

The datalink functionality was not tested extensively during the simulation periods due to time constraints.

4.1.3.4. Planning and sequencing function

The software function for Runway Planning was not provided for implementation on the SAMS platform. Runway Planning functionality could not therefore be evaluated.

The taxiway planning function is reliant upon the guidance and control functions. The objective of the taxiway planning function is to give guidance to the controller as to the optimum route to assign to aircraft. Initial feedback from the participating controllers indicates that they see the benefits from this function being limited.

The taxiway planning module of SAMS is intended to cover two types of planning: strategic (in advance of issuing a clearance) and tactical (introducing real time changes to the assigned route due to obstacles or movement delays as determined by the control module. When calculating a route, it takes into account certain constraints that can be entered by the user at start-up and looks for the shortest route in distance between a stand and a runway.

Time constraints and the fact that the planning module consumed considerable computing power, making it not useable in real-time, made it not possible to extensively test the SAMS planning function.

4.1.3.5. Guidance Function

The software function for Guidance was not integrated, due to interface problems and the short time available for integration. Therefore, its functionality could not be evaluated.

4.1.3.6. Controller HMI

A good, user-friendly interface is vital during the introduction of new operational systems. The HMI is the first thing that a controller sees when using the system. Therefore, if insufficient effort is devoted towards the HMI, there is a possibility that the user may reject the whole system due to frustration with specific elements of the HMI. This section presents some issues regarding the SAMS HMI.

HMI user friendliness:

The design of the HMI appears to be focused on the role of the ground controller, and that the requirements of the air Arrivals / Departures controller (a.k.a. the Local Controller) have only been taken into account as an addendum. For example, traffic approaching from the bottom of the screen cannot be displayed in the same orientation as the real view. However, the impact of this constraint may be limited, as the same controller would not be working both roles at the same time. It is difficult for the controllers to get used to the different layouts (final approach and movement area / ramp) of the two parts of the screen. It is recommended that the Distance From Touchdown Indicator (DFTI) lines should be represented as an extension of the runway centre line rather than being placed in a dedicated window. The controllers could then have been able to zoom out to see the traffic on final approach. The supplementary window, also know as the radar inset window, should be able to also present the expanded view incorporating the final approach, and not only a small zoomed area of the airport. Such a solution would enable the controllers to use the display to meet their different situational awareness requirements. Additionally, the ability to rotate the surface display is a useful feature of the HMI and provides a solution to the above-mentioned problem of the real view orientation.

The controllers recommended that an Aerodrome Traffic Monitor (ATM) be incorporated into the system. The ATM is used at Heathrow to monitor departing aircraft as well as arriving aircraft. The Departures controller uses the ATM to ensure that the aircraft have started the turn published in the applicable SID prior to clearing the subsequent aircraft to take-off.

In general, the HMI does not provide many customisation features to help the end user adapt to the system. The different modules of the SAMS platform had to be configured at the servers in Amsterdam. This process required a considerable amount of telephone co-ordination and tended to be a slow process. However, the simulation objectives were focused upon system issues, and the HMI changes therefore had a lower priority. Consequently, some minor HMI updates were made available in the next period of simulations, although other suggestions were never taken into account. The availability of an on-line configuration tool would have enabled quick changes to be made to the HMI between simulation runs.

The Schiphol controllers noted that the zoom function and the availability of an inset window on the HMI were useful features. The controllers stated that it would be preferable to have independent zoom factors on each of the windows.

Fonts and colours:

The most important concern is that the chosen colours and fonts would not be easy to see in visual control room light conditions. It was difficult to distinguish between some colours and fonts in the ATS facility light conditions, which are probably darker than an average environment.

Input devices, windows and buttons:

The means of selection for the different tools is good. However, making the size of the buttons larger could increase ease of selection. It was also noted that sometimes too many steps are needed to reach a particular function. The number of steps to perform certain actions should be rationalised.

It was noted that the Flight Plan Lists window does not have a title. This may result in the initial familiarisation of the HMI being slower. The list of flights did not appear to be clearly ordered. There appeared to be no relationship between the listed flights and the actual traffic situation. It is recommended that a list of flight plan is ordered with reference to a visible field so it is clear which sort criteria have been applied.

It should be noted that a real implementation of a controller HMI would probably be made on a 2K x 2k screen, where SAMS used two large workstation monitors (19’’). A larger screen enables more information to be displayed on the HMI.

Labels:

An enhancement that could help to clarify the HMI is the ability to select the automatic orientation of labels depending on the user preferences, i.e. all labels to be presented at a bearing of 045 from the track symbol. Moreover, the ability to manually orientate a specific individual label is also desired.

The Schiphol controllers suggested that the apron area surrounding the gates could be blanked from the HMI. This would enable the amount of clutter due to traffic which is either stationary or slow moving, i.e. pushing back / approaching gates, to be reduced from the HMI.

4.1.4. General feedback on the SAMS platform

This section describes some general issues that have been gathered by the technical staff of and observers from the SAMS simulations.

4.1.4.1. Co-ordination issues

One of the biggest challenges in running the simulations on the SAMS platform was the real time co-ordination of the various sites involved in the simulation: mainly the NLR sites (where the ASMGCS functions have been integrated) and the DLR site (where the ATS is located). The third site to co-ordinate was the DERA site with the LATCH (747 Boeing simulator).

The inter-site communication was initially insufficient. Only one internal, one external, and one mobile phone were available. These were all used by the SAMS simulation co-ordinator, causing high workload and problems for the distribution of actual information among participants. The SAMS team suggested a proposal for improved communication (e-mail with group addressing and more telephone lines), but this could only be implemented for the second demonstration period.

Co-ordination activity for real-time simulation is an issue that could potentially be improved upon in the context of possible future use of this platform. Throughout the evaluation period, extensive co-ordination was required between the participating sites, mainly between the DLR and NLR facilities.

The first category of co-ordination to be handled is the launch of the various applications distributed at each site. An enhanced automated co-ordination process for the set up of the various applications selected for a given simulation run could result in a reduction in the time required to initialise the system. Due to time pressure during the SAMS development phases, this feature had not been given priority.

The second type of co-ordination is the real time control of the run, especially when a software crash occurs at a given site. During the simulations, a number of crashes took place at the NLR site that required a restart of some applications. Most of these crashes were due to the surveillance function. No provision had been made to automatically support the supervision role and manual intervention was always required. This task was very time consuming for the project co-ordinator, who relied upon communicating by mobile phones to manage the sequential application restart.

For future SAMS platform use, it is recommended that a centralised co-ordination position be implemented covering the various sites involved in the simulation run. Due to the fact that the evaluation site is at the DLR facility, it is proposed that the co-ordination position also be implemented at the DLR site.

Alternatively, a future version of the SAMS platform could be geographically simplified thereby significantly reducing the complexity of the existing SAMS platform and de facto resolving this issue.

The communication between pilots and controllers was acceptable, except for the connection between Bedford DERA and the controllers. The Bedford pilot was hardly audible in the tower. This was due to the interim fix that was used to enable communication between the B747 simulator and the tower.

4.1.4.2. Availability of the SAMS platform

The introduction of a visual context provision within the basic SAMS platform function resulted in the availability of the SAMS platform being directly linked to the availability of the DLR ATS facility.

The DLR ATS facility is extensively used for the initial training of air traffic controllers in the frame of various support contracts between DLR and various ATC service providers. Due to the business priority given to this activity the utilisation of this control tower simulator could be one of the largest limitations in terms of platform availability in the future.

The DERA facility is also a commercial tool used by many other activities and projects. The LATCH may also have limited availability for future evaluation activities.

The practical non availability of the SAMS platform for future R&D work due to commercial projects requiring the use of the ATS / LATCH facilities raises a significant concern for future R&D using such a platform.

One way to resolve this potential limitation in availability could be to reassess the requirement for a visual context presentation in future simulations to support the evaluation of benefits of ASMGCS. If an external visual system is deemed not to be essential for ASMGCS simulations, a simplified platform could be used for future work.

During the development of the A-SMGCS functions, namely surveillance, guidance, control and routing/planning, a lot of preliminary research (for example the conflict detection and alert) can be done before a full presentation with the external visual system is made to operational users. As many of the functions have their main benefit in LVP conditions, useful work can be done using HMIs alone, but full validation will necessitate the use of the visual system.

However the following points need to be borne in mind when designing this type of experiment :

- For a realistic traffic sample and controller-pilot interaction, there is still a need for pseudo-pilots and a function that provides realistic surveillance information from the pseudo-pilots’ actions (i.e. the function performed by the exercise engine).

- Controllers benefit from having a familiar environment, particularly at the beginning of a project, and for controllers coming from a non-A-SMGCS environment this will require the provision of external visuals.

- Traffic scenarios and procedures must be sufficiently close to current practice to allow the controllers to immerse themselves in the simulations without too much adjustment.

Finally, not only the platform must be available, also the developers of the different software component must be ready to test and possibly update their software functions. This was a particularly difficult task in SAMS, since the platform was running at different sites. Observerations had to be made in Braunschweig at the ATS facility, while the software are running in Amsterdam, in the A-SMGCS simulator.

4.2. POTENTIAL BENEFITS

SAMS has been the first implementation of an A-SMGCS evaluation platform. In general, despite certain functions being unavailable, the simulations have proved the technical feasibility of an A-SMGCS multi-site real-time man-in-the-loop platform. It gave a first awareness of the new concept and a first impression of what users demand.

The SAMS documentation gives a good design of an A-SMGCS architecture and defines in details the interfaces between the components of A-SMGCS. A first step in the standardisation of software interfaces and has been provided.

The SAMS platform provides significant improvements in the evaluation of new A-SMGCS functions and procedures. Controllers and pilots are given the possibility to examine new functions in a real-time simulation environment that closely resembles their current operational environment and as such are given the possibility to comment on dedicated functions. The SAMS trials have proven that controllers feel “at home”, even in a simulated environment. The controllers participating in the simulations found that the throughput of aircraft and the traffic samples were acceptable as a baseline for good visibility daylight operations.

Airport authorities are given the means to examine new procedures and test them thoroughly before new procedures can be put in place. It must be noted that the new HALS/DTOP procedure in Frankfurt has been extensively tested in the ATS simulation environment, before it was put in place. Furthermore, controllers are given the possibility to be trained in new procedures.

A major advantage of simulation is that dangerous situations can be controlled, tested, and repeated without putting people and equipment at risk. Situations like runway incursions cannot be tested in real life and must be evaluated in a simulated environment. Although much work can be done in an environment without visual clues, the benefits of a visual simulator are enormous. Related to this, is the fact that observers can interact with controllers and even distract them at any moment without creating potential hazardous situations.

SAMS connected several simulators in different locations. Although this was performed before in connecting flight simulators and ATC simulators, it had never been done before with an A-SMGCS component. The difference is that now two simulators will need to be manned by the same personnel (the tower visual simulator and the A-SMGCS simulator), although the simulators themselves are in geographically different locations. Both simulators need to respond in exactly the same manner and need to co-operate. Information exchange between the simulators is much more than just positional information.

The shared use of different expensive simulators makes it possible to perform more extensive trials than is currently the situation with any European (research) institute.

4.3. PROPOSALS FOR FURTHER WORK

With A-SMGCS being a novel concept, an almost permanent (or at least easy to rebuild) simulation platform should be available to in-depth evaluations. Two aspects have been evaluated during the SAMS trials, technical and validation.

As a general comment, we would like to highlight the importance of this kind of tools for the research and development of A-SMGCS functions and procedures. SAMS is capable to keep both controllers and pilots in the loop, so that they can experience the results of the new concept and feed back quickly to the researchers. Due to the fact that the airport environment is so complicated to simulate because of the very different aspects of the airport control (for instance, the need of visual contact), the SAMS project involved facilities create a brilliant frame to test and go further on the still young A-SMGCS concept.

Nevertheless, there is still a lot of work to be done, and the improvement of the platform itself is one of the points to be taken into account. It would be a pity that all the effort put in the integration of these three simulators would be partially lost and useless because it does not fulfil completely what was initially expected. Taking into account the experience on automating air traffic management systems, it is never easy to reach a very big objective in only one step. Much better is to start taking little steps that can be useful by themselves, and keep on upgrading the tool to achieve a better product; a spiral life cycle model would probably give better results.

4.3.1. *Technical*

One of the basic requirements for any A-SMGCS simulation platform is that it must be configurable to support the simulation of various airport environments. The potential future use of the SAMS platform is linked to the ease with which it can adapt to various contexts. The ATS simulator proved very flexible in switching between different airport environments. However, it is suggested that for future simulations, more time should be allocated for *preparation* of the pseudo pilot station, the databases, and the simulator traffic. One of the major concerns when using a simulator is the adaptation capability of the tool. In the SAMS platform, when starting the simulation for a new airport, it will be necessary to prepare four different views of its topology, that is, one for the SAMS HMI, one for the ATS visuals, one for the LATCH visuals and one more for the pseudo pilots HMI. This can take about 6 months of work. Of course, once an airport is modelled, there are many possible uses of the platform.

There was a need for a longer period of technical tests and validation, completely separated from the operational evaluation with pilots and controllers. The SAMS contract did not foresee in more use of all simulators, so that the decision was made to do technical testing together with operational use. In future, more effort should be spend on technical tests.

There is a need for a platform for testing the A-SMGCS functions, especially for the software engineers. Such a platform should provide a traffic generation function, which should give the possibility for quickly testing several scenarios. Besides traffic generation, advanced functions will need inputs from other functions. It is recommended that the SAMS functions be provided with basic or empty functionality to enable testing of each real implementation of a component separately. This concept can be implemented in a *driver* and *stub* architecture. Drivers provide triggers for functions, e.g. the guidance functions needs plans, which can be made beforehand according to predefined rules. Stubs provide empty routines that give a predefined result, e.g. the HMI will depend on many different functions, but the contents does not always have to be precisely correct just for testing. Drivers and stubs may be separated from the A-SMGCS platform in order to perform small in-house testing of functions.

A good technical simulation environment must be made available. In the SAMS project, the “nice-to-have” features (like an HMI colour and font editor or a scenario selection facility in the simulation manager) had mostly been eliminated from the platform, because of time and budget constraints. Besides, some functions just were not available, such as a CORBA monitoring device. The new versions of CORBA provide much better facilities for technical simulation support. This includes monitoring of the operational status of the software functions, to see e.g. that one function has crashed. Better support must also be provided to restart the functions, without the necessity to restart one complete simulator (e.g. in some occasions, the tower and flight simulators kept on running, while the complete A-SMGCS simulator needed a restart after a crash of one of the functions).

A standard for interfaces between A-SMGCS component must be defined. Together with data formats, communication protocols need to be installed. The SAMS documentation gives a good impetus.

4.3.2. Evaluation

The SAMS requirements should be re-evaluated and enriched with the comments from the controllers and pilots that participated in the trials.

Two issues that have been considered as major difficulties during the validation period are:

- The difficulty in the global co-ordination of the simulation involving applications on various sites.
- The practical availability of the SAMS platform and in particular the availability of ATS.

In order to resolve these two issues it is recommended that the need for visual context presentation that implies the integration of the ATS facility and its associated constraints be reviewed. If this visual context is not a strong requirement, the SAMS platform architecture can be reconsidered and changes made in order to make the platform available for further zero-visibility A-SMGCS simulations.

Of course, SAMS only gave a first impression of what users would want from A-SMGCS. The ATOPS project already gave some more possibilities to objectively evaluate the platform. Still, the period was too short for real research and evaluations. More tests could be performed on a similar platform.

Evaluations should be performed per module, possibly focussing on only one (or a few) aspect(s) of this module. Not all modules can be tested at the same time. Any A-SMGCS platform should be configurable w.r.t. functions that participate in a simulation and must be extendable. Evaluations must be performed on single functions, taking into account updated requirements of other modules.

As stated before, the effort needed to implement an airport in four different ways to make the platform work is so big that it would be necessary to foresee a complete demonstration programme for the implemented airport, in order to gain from the invested work. Once the effort is made, numerous possibilities exist to exploit it.

ANNEX I – List of publications

An. *Der Rollverkehr Soll Besser Flieβen*, Braunschweiger Zeitung, 11 February 2000 (in German).

ANNEX II – LIST OF CONFERENCES AND PRESENTATIONS

SAMS and ATOPS, An Overview by R. Pantelides and H. Maycroft at the FAA/Eurocontrol Co-operative Effort on Air Traffic Management Decision Support Tools – A-SGMCS Technical Interchange Meeting from Action Plan 6, 10-12 November, 1998, Braunschweig.

The SAMS Project by Philippe Dubernet, 2nd OPTAS-B Workshop and 4th EC DG VII Inter-project meeting, 20-21 January 1999, Rome.

AENA will provide a presentation of the SAMS results to the AOT meeting in September 2000.

ANNEX III – CONFLICT ALERT RULES

Refence 12 describes the conflict alert rules for Schiphol.

In the following table rules for generating a warning and alert are given using the following convention:

> If ***Condition 1*** is true and ***Condition 2*** (if present) is true and ***Condition 3*** (if present) is true, then an alert of the type ***Type of Alert*** is to be produced.

A “warning alert” tells the ATCO that a situation has occurred that needs special attention.
An “critical alert” tells the ATCO that a critical situation may occur.

All rules are to be tested at least once a second.

Schiphol rules for a Basic runway incursion alert (BRIA)

Rule number	***Condition 1***		***Condition 2***		***Condition 3***		***Type of alert***
1	An arriving aircraft is estimated to be T_1 seconds or less from runway threshold	*AND*	There is a target in the yellow area			*THEN*	Warning alert
2	An arriving aircraft is estimated to be T_1 seconds or less from runway threshold	*AND*	There is a target in the red area			*THEN*	Critical alert
3	An aircraft is in the red area	*AND*	There is a target in the yellow area			*THEN*	Warning alert
4	An aircraft is in the red area	*AND*	There is a target in the red area			*THEN*	Critical alert

Schiphol rules for an Advanced runway incursion alert (ARIA)

Rule number	***Condition 1***		***Condition 2***		***Condition 3***		***Type of alert***
1.	An arriving aircraft is estimated to be T_2 seconds or less from runway threshold	*AND*	Good visibility	*AND*	There is a target in the yellow area	*THEN*	Warning alert
2.	An arriving aircraft is estimated to be T_3 seconds or less from runway threshold	*AND*	Good visibility	*AND*	There is a target in the red area	*THEN*	Critical alert
3.	An arriving aircraft is estimated to be T_1 seconds or less from runway threshold	*AND*	Low visibility	*AND*	There is a target in the yellow area	*THEN*	Warning alert
4.	An arriving aircraft	*AND*	Low visibility	*AND*	There is a target	*THEN*	Critical

	is estimated to be T_2 seconds or less from runway threshold				in the red area		alert
5.	An arriving aircraft has passed the threshold	*AND*	There is a target inside the yellow area	*AND*	target is ahead of the landing aircraft	*THEN*	Warning alert
6.	An arriving aircraft has passed the threshold	*AND*	There is a target inside the red area	*AND*	target is ahead of the landing aircraft	*THEN*	Critical alert
7.	A departing aircraft is moving along the runway	*AND*	There is a target inside the yellow area	*AND*	target is ahead of the departing aircraft	*THEN*	Warning alert
8.	A departing aircraft is moving along the runway	*AND*	There is a target inside the red area	*AND*	target is ahead of the departing aircraft	*THEN*	Critical alert

Heathrow rules for a runway incursion alert

Rule number	***Condition 1***		***Condition 2***		***Condition 3***		***Type of alert***
1	An arriving aircraft is estimated to be 30 seconds or less from runway threshold	*AND*	Good visibility	*AND*	There is a target on the runway	*THEN*	Warning alert
2	An arriving aircraft is estimated to be 60 seconds or less from runway threshold	*AND*	Low visibility	*AND*	There is a target inside the runway ILS protection area	*THEN*	Warning alert
3	An arriving aircraft is estimated to be 15 seconds or less from runway threshold	*AND*	Good visibility	*AND*	There is a target on the runway	*THEN*	Critical alert
4	An arriving aircraft is estimated to be 30 seconds or less from runway threshold	*AND*	Low visibility	*AND*	There is a target inside the runway ILS protection area	*THEN*	Critical alert
5	An arriving aircraft has passed the threshold	*AND*	There is a target ahead of the arriving aircraft on the runway			*THEN*	Critical alert
6	There is more than one target present on the departure runway					*THEN*	Warning alert
7	The speed of a departing aircraft along the runway is greater than 60 knots	*AND*	There is a target ahead of the departing aircraft on the runway			*THEN*	Critical alert

Heathrow rules for a taxiway conflict alert

Rule number	***Condition 1***		***Condition 2***		***Condition 3***		***Type of alert***
1	Traffic is holding at the 81/104(o) stop bar	*AND*	An aircraft of type B747, A330, A340, B777, IL96 routing from block 104(o) to 60(o)			***THEN***	Critical alert
2	Traffic is holding at the 81/104(o) stop bar	*AND*	An aircraft of type B747, A330, A340, B777, IL96 routing from block 60(o) to 104(o)			***THEN***	Critical alert
3	B744 aircraft parked on stand RS1	*AND*	An aircraft of type A330, A340, B747, B777, IL96 routing from block 90 to 96			***THEN***	Critical alert

Note: The rules above are not exhaustive they are intended to provide an example for the SAMS Heathrow demonstration experiment only.

Heathrow rules for prohibited taxi routes (e.g. wingtip clearance alert or an absence of markings and/or lighting)

Rule number	***Condition 1***		***Condition 2***		***Condition 3***		***Type of alert***
1	Traffic is routed along 19-18-137					*THEN*	Warning alert
2	Traffic is routed along 18-137-134					*THEN*	Warning alert
3	Traffic is routed along 137-134-133					*THEN*	Warning alert
4	Traffic is routed along 134-133-40					*THEN*	Warning alert
5	Traffic is routed along 134-19-40					*THEN*	Warning alert
6	Traffic is routed along 40-19-8					*THEN*	Warning alert
7	Traffic is routed along 8-40-19					*THEN*	Warning alert
8	Traffic is routed along 43-40-133					*THEN*	Warning alert
9	Traffic is routed along 95-118-86	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
10	Traffic is routed along 95-118-86	*AND*	The aircraft is larger than a G5			*THEN*	Warning alert
11	Traffic is routed					*THEN*	Warning

	along 81-104(O)-60(O)						alert
12	Traffic is routed along 81-60(o)-104(o)					*THEN*	Warning alert
13	Traffic is routed along 53-50-48					*THEN*	Warning alert
14	Traffic is routed along 53-50-56					*THEN*	Warning alert
15	Traffic is routed along 73-62(i)-63(i)					*THEN*	Warning alert
16	Traffic is routed along 94-95-88					*THEN*	Warning alert
17	Traffic is routed along 85-72(o)-77(o)					*THEN*	Warning alert
18	Traffic is routed along 81(RET)-60(o)					*THEN*	Warning alert
19	Traffic is routed along 126-65-46	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
20	Traffic is routed along 105-loop-100	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
21	Traffic is routed along 53-54-48	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
22	Traffic is routed along 53-50-Maintenance Area	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
23	Traffic is routed along 46-65-126	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
24	Traffic is routed along 100-loop-105	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
25	Traffic is routed along 48-54-53	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
26	Traffic is routed along Maintenance Area-50-53	*AND*	It is outside the hours of daylight			*THEN*	Warning alert
27	An aircraft of type B747, B777, IL96, AN4R, C5/C5A A330, A340 is routing from block to 72(I) to 61 (i)	*AND*	The aircraft is not being towed			*THEN*	Warning alert
28	An aircraft of type B747, B777, IL96, AN4R, C5/C5A A330, A340 is routing through block 25(i)	*AND*	The aircraft is not being towed			*THEN*	Warning alert
29	An aircraft of type B747, B777 is routing through blocks 120-119-91	*AND*	The aircraft is not being towed			*THEN*	Warning alert

Heathrow rules for protection of the localiser sensitive area

Rule number	*Condition 1*		*Condition 2*		*Condition 3*		*Type of alert*
1	Low visibility operations in progress	*AND*	Runway 09R is the landing runway	*AND*	An aircraft is taxiing or towed via 85-72(O)-77(O)	***THEN***	Critical alert
2	Low visibility operations in progress	*AND*	An aircraft is on approach to 09R	*AND*	An aircraft is block 105	***THEN***	Critical alert
3	Low visibility operations in progress	*AND*	An aircraft is on approach to 09R	*AND*	An aircraft is block 106	***THEN***	Critical alert
4	Low visibility operations in progress	*AND*	An aircraft is on approach to 09L	*AND*	An aircraft is proceeding westwards beyond the 35/36 stop bar	***THEN***	Critical alert
5	Low visibility operations in progress	*AND*	An aircraft is on approach to 27L	*AND*	An aircraft is routing 94-88-95	***THEN***	Critical alert
6	Low visibility operations in progress	*AND*	An aircraft is on approach to 27L	*AND*	An aircraft is routing 95-88-94	***THEN***	Critical alert

Heathrow rules for protection of the glidepath critical area

Rule number	*Condition 1*		*Condition 2*		*Condition 3*		*Type of alert*
1	Low visibility operations in progress	*AND*	An aircraft is less than 10NM away on approach to 27L	*AND*	An aircraft or a vehicle is in block 87	***THEN***	Critical alert
2	Low visibility operations not in progress	*AND*	An aircraft is less than 10NM away on approach to 27L	*AND*	An aircraft or a vehicle greater than 3m in height is in block 87	***THEN***	Critical alert
3	Low visibility operations not in progress	*AND*	An aircraft is less than 4NM away on approach to 27L	*AND*	An aircraft or a vehicle is in block 87	***THEN***	Critical alert