Doc 9830
AN/452

Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual

Approved by the Secretary General
and published under his authority

First Edition — 2004

International Civil Aviation Organization

Published in separate English, Arabic, Chinese, French, Russian and Spanish editions by the International Civil Aviation Organization. All correspondence, except orders and subscriptions, should be addressed to the Secretary General.

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3/08

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AMENDMENTS

The issue of amendments is announced regularly in the *ICAO Journal* and in the monthly *Supplement to the Catalogue of ICAO Publications and Audio-visual Training Aids*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
No.	Date	Entered by

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FOREWORD

The systems described in the ICAO *Manual of Surface Movement Guidance and Control Systems (SMGCS)* (Doc 9476) are not always capable of providing the necessary support to aircraft operations in order to maintain required capacity and safety levels, especially under low visibility conditions. An advanced surface movement guidance and control system (A-SMGCS), therefore, is expected to provide adequate capacity and safety in relation to specific weather conditions, traffic density and aerodrome layout by making use of modern technologies and a high level of integration between the various functionalities.

Due to the availability and development of new technologies, including automation, it is possible to increase aerodrome capacity in low visibility conditions and at complex and high-density aerodromes. In order to avoid a technology-driven approach, generic operational requirements were developed (see Chapter 2) which, irrespective of the technology used, provide guidelines for the analysis and development of local requirements.

The performance requirements contained in this manual (see Chapter 4) are intended to provide a possible solution to safety- or capacity-related problems that have been identified up to this date. The A-SMGCS concept (see Chapter 1), however, is expected to continue to evolve as and when technology, systems and procedures are developed.

The operational and performance requirements contained herein (see Chapters 3 and 4) are considered to be necessary for the selection, development and implementation of an A-SMGCS at an aerodrome where the current SMGCS needs to be upgraded, or for the introduction of an A-SMGCS at an aerodrome which currently has no SMGCS, but where the traffic density and/or aerodrome layout requires one.

This manual is intended as guidance to enable manufacturers and operators, as well as certifying authorities, to develop and introduce A-SMGCS depending on local circumstances and taking into account global interoperability requirements for international civil aviation operations. Applicable ICAO Standards and Recommended Practices (SARPs) should also be taken into consideration in the development and implementation of A-SMGCS.

ACRONYMS, ABBREVIATIONS AND SYMBOLS

Acronyms and Abbreviations

ADREP	Accident/Incident Data Reporting (ICAO)
ADS-B	Automatic dependent surveillance — broadcast
ARP	Aerodrome reference point
ARTS	Automated radar terminal system
ASDE	Airport surface detection equipment
A-SMGCS	Advanced surface movement guidance and control system(s)
ASR	Aerodrome surveillance radar
ATC	Air traffic control
ATCO	Air traffic controller
ATIDS	Aerodrome target identification system
ATM	Air traffic management
ATS	Air traffic services
AVOL	Aerodrome visibility operational level
B	Basic
C	Complex
CDB	Capacity/demand balance
CFMU	Central Flight Management Unit
CWP	Controller working position
DEFAMM	Demonstration Facilities for Aerodrome Movement Management (European Commission)
D-GNSS	Differential global navigation satellite system
DLM	Data link manager
ECAC	European Civil Aviation Conference
ETA	Estimated time of arrival
ETD	Estimated time of departure
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration (U.S.)
ft	Foot
h	Hour
H	Heavy
HMI	Human-machine interface
ICAO	International Civil Aviation Organization
ILS	Instrument landing system
km	Kilometre
kt	Knot
L	Light
LAAS	Local area augmentation system
LAN	Local area network
LSS	Loop sensor sub-system
m	Metre
M	Medium
NM	Nautical mile
NOTAM	Notice to airmen
NTSB	National Transportation Safety Board (U.S.)
PD	Probability of detection
PDA	Probability of detection of an alert
PDAS	Pilot/driver assistance system
PFA	Probability of false alert
PFD	Probability of false detection
PFID	Probability of false identification
PID	Probability of identification
RIRP	Runway Incursion Reduction Programme (FAA)
RNP	Required navigation performance
RVR	Runway visual range
s	Second
S	Simple
SARPs	Standards and Recommended Practices
SID	Standard instrument departure
SMGCS	Surface movement guidance and control system(s)
SMR	Surface movement radar
SSDS	Surface surveillance data server
STAR	Standard instrument arrival
TDMA	Time division multiple access
TDOA	Time difference of arrival
TLS	Target level of safety
VDGS	Visual docking guidance system
VFR	Visual flight rules
VHF	Very high frequency
WGS-84	World Geodetic System — 1984

Symbols

°	Degree
=	Equals
>	Greater than
<	Less than
–	Minus
%	Per cent
+	Plus
±	Plus or minus

GLOSSARY

Note.— Some terms provided below are taken from existing ICAO documents, e.g. Annex 14.

Advanced surface movement guidance and control system (A-SMGCS). A system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety.

Aerodrome. A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

Aerodrome visibility operational level (AVOL). The minimum visibility at or above which the declared movement rate can be sustained.

Airport authority. The entity responsible for the operational management of the airport.

Alert. An indication of an existing or pending situation during aerodrome operations, or an indication of an abnormal A-SMGCS operation, that requires attention and/or action.

Note.— The term alert covers warnings, cautions, advisories and alarms reflecting different levels of urgency or equipment performance.

Apron. A defined area, on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance.

Apron management service. A service provided to regulate the activities and the movement of aircraft and vehicles on an apron.

A-SMGCS capacity. The maximum number of simultaneous movements of aircraft and vehicles that the system can safely support with an acceptable delay commensurate with the runway and taxiway capacity at a particular aerodrome.

Conflict. A situation where there is a risk for collision between aircraft and/or vehicles.

Identification. The correlation of a known aircraft or vehicle call sign with the displayed target of that aircraft or vehicle on the display of the surveillance system.

Incursion. Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected areas of a surface designated for the landing, take-off, taxiing and parking of aircraft.

Manoeuvring area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons.

Movement area. That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and apron(s).

Note.— For A-SMGCS, the movement area does not include passive stands, empty stands and those areas of the apron(s) that are exclusively designated to vehicle movements.

Obstacle. All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight.

Reversion time. Maximum time for reversion to manual light control to be completed.

Road. An established surface route on the movement area meant for the exclusive use of vehicles.

Route. A track from a defined starting point to a defined end point on the movement area.

Runway incursion. Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.

Stand. A designated area on an apron intended to be used for the parking of an aircraft. Stands can be classified as:

a) active stand — a stand that is occupied by a stationary aircraft with engines operating, or on which an aircraft is moving, or that is being approached by an aircraft;

b) passive stand — a stand that is occupied by a stationary aircraft with engines not operating; or

c) empty stand — a stand that is vacant and not being approached by an aircraft.

Surveillance. A function of the system which provides identification and accurate position information on aircraft, vehicles and obstacles within the designated area.

System accuracy. A degree of conformance between the estimated or measured value and the true value.

Note.— For A-SMGCS, this includes the position and the speed.

System availability. The ability of an A-SMGCS to perform a required function at the initiation of the intended operation within an area covered by the A-SMGCS.

System continuity. The ability of an A-SMGCS to perform its required function without non-scheduled interruption during the intended operation within an area covered by the A-SMGCS.

System integrity. System integrity relates to the trust which can be placed in the correctness of the information provided by an A-SMGCS. This includes the ability of an A-SMGCS to provide timely and valid alerts to the user(s) when the A-SMGCS must not be used for the intended operation.

System reliability. The ability of an A-SMGCS to perform a required function under given conditions for a given time interval.

Target. An aircraft, vehicle or obstacle that is displayed on a surveillance display.

Target level of safety (TLS). The probability of an accident (fatal or hull loss) during aircraft movement on the aerodrome.

Chapter 1

INTRODUCTION

1.1 SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEM (SMGCS) OPERATIONS

1.1.1 Current SMGCS procedures are based primarily on the principle "see and be seen" to maintain spacing between aircraft and/or vehicles on the aerodrome movement area. However, the number of accidents and incidents during surface movements, including runway incursions, is increasing. Contributing factors include the increasing number of operations that take place in low visibility conditions,* the progressive increase in traffic, the complexity of aerodrome layouts, and the proliferation of capacity-enhancing techniques and procedures. Therefore, advanced capabilities are needed to ensure spacing when visual means are not adequate and to maintain aerodrome capacity in all weather conditions.

1.1.2 Generally, operations at an aerodrome are dependent on air traffic controllers, pilots and vehicle drivers using visual observations to estimate the respective relative positions of aircraft and vehicles. Pilots and vehicle drivers rely on visual aids (lighting, markings and signage) to guide them along their assigned routes and to identify intersections and holding positions. During periods of low visibility, controllers must rely on pilots' reports and surface movement radar to monitor spacing and to identify potential conflicts. Under these conditions, pilots and vehicle drivers find that their ability to operate "see and be seen" is severely impaired. There are no prescribed separation minima, and controllers, pilots and vehicle drivers share the responsibility that operations will not create a collision hazard.

1.1.3 All aerodromes have some form of SMGCS. Commonly used systems that have been installed in the past are described in the *Manual of Surface Movement Guidance and Control Systems (SMGCS)* (Doc 9476). In their simplest form, SMGCS consist of painted guidelines and signs, while in their most advanced and complex form, they employ switched taxiway centre lines and stop bars. All SMGCS provide guidance to aircraft from the landing runway to the parking position on the apron and back to the runway used for take-off, as well as for other movements on the aerodrome surface such as from a maintenance area to an apron, or from an apron to an apron. In addition, SMGCS provide some guidance to vehicles. Normally, control of the activities and the movement of aircraft and vehicles rests with air traffic control (ATC) with respect to the manoeuvring area. In the case of aprons, such responsibility sometimes rests with the apron management. Lastly, SMGCS may also provide guidance to, and control or regulation of, personnel authorized to be on the movement area of an aerodrome.

1.1.4 For low visibility operations, plans of SMGCS prescribe the operational procedures that must be followed during surface movements. Procedures vary from aerodrome to aerodrome depending on factors such as the regulations and policies of air traffic services (ATS), the organizational responsibilities, and the aerodrome configuration and facilities.

1.1.5 Low visibility SMGCS procedures are put into effect when the runway visual range (RVR) decreases to a predetermined value (usually between 400 m and 600 m). Notifications are then issued to the aircraft operators, and checklists are used to implement the low visibility procedures.

1.1.6 In low visibility, designated low visibility taxi routes may be used and depicted on aerodrome charts available to pilots and vehicle drivers. Lighting systems such as stop bars and runway guard lights are used to assist ATC in controlling access to active runways. Landing aircraft exit the runway at specific taxiways and follow the taxi instructions from the ground controller. Access of ground vehicles is strictly controlled, and only essential vehicles are permitted on the movement area.

1.1.7 At present, procedures permit aircraft to land in conditions down to zero visibility and to take off when the

* See Appendix A for the definition of visibility conditions used in this manual.

RVR is reduced to approximately 75 m. Although some States use sophisticated taxiway guidance systems with stop bars to control movements, there are no ICAO provisions for the operation of an SMGCS which can provide for expedition and safety in all weather conditions.

1.2 GOALS FOR IMPROVING SMGCS

The following high-level goals provide a basis for considering what capabilities are required, and may be useful in developing improvements for surface movement operations:

a) controllers, pilots and vehicle drivers should be provided with systems of the same level of performance;

b) controllers, pilots and vehicle drivers should have clearly defined roles and responsibilities that eliminate procedural ambiguities which may lead to operational errors and deviations;

c) improved means of providing situational awareness should be available to controllers, pilots and vehicle drivers, taking into consideration visibility conditions, traffic density and aerodrome layout;

d) improved means of surveillance should be in place;

e) delays in ground movements should be reduced, and growth in operations, including runway capacity, should be accommodated;

f) surface movement functions should be able to accommodate all classes of aircraft and necessary vehicles;

g) improved guidance and procedures should be in place to allow:

   1) safe surface operations on the aerodrome, taking into consideration visibility, traffic density and aerodrome layout; and

   2) pilots and vehicle drivers to follow their assigned routes in an unambiguous and reliable way;

h) improved aerodrome visual aids providing guidance for surface movements should be an integrated component of the system;

i) automation and Human Factors engineering should provide the linkage between the surface and the terminal and between the terminal and the en-route airspace to create seamless operations with reduced controller and pilot workload;

j) SMGCS improvements should be developed in a modular form to accommodate all aerodrome types; and

k) conflict prediction and/or detection, analysis, and resolution should be provided.

1.3 A-SMGCS CONCEPT

1.3.1 An A-SMGCS differs from an SMGCS in that it may provide a full individual service over a much wider range of weather conditions, traffic density and aerodrome layouts. A-SMGCS are to use common modules in all circumstances. The modules to be used in any particular circumstance are determined by the specific requirements of each aerodrome.

1.3.2 The use of an A-SMGCS will lead to reallocation of responsibilities for various system functions. Less reliance will need to be placed on the ability of the pilot or control authority to provide visual surveillance. Some functions will use automation to provide routing, guidance and control.

1.3.3 The main benefits to be accrued from the implementation of an A-SMGCS will be associated with, but not limited to, low visibility surface operations. Significant improvements in aerodrome capacity can also be achieved under good visibility conditions.

1.3.4 The significant distinctions between the functions of a current SMGCS and an A-SMGCS are that the latter should provide more precise guidance and control for all aircraft and vehicles on the movement area, and should also be able to ensure spacing between all moving aircraft and vehicles, especially in conditions which prevent spacing being maintained visually. It is therefore important to recognize that, except where the total number of aircraft and vehicles permitted to operate on the movement area at any one time is kept very low, such tasks are beyond the capability of a controller even if aided by conventional surface movement radar (SMR). Therefore, an A-SMGCS should provide situation awareness not only to ATC but also to those aircraft and vehicles that are liable to come in proximity to each other.

1.3.5 Complex traffic flows may require an A-SMGCS to function as a surface management system by providing for the planning and management of all aircraft and authorized vehicles on the movement area while interfacing with the air traffic management (ATM) system.

1.3.6 An A-SMGCS addresses future increases in surface movement operations that would lead to increased surface congestion and system delays unless new techniques were made available to the air traffic controller to reduce workload. From the flight dispatch/apron management perspective, more sharing of information will be needed to manage the availability of stands/parking areas, thereby reducing taxi delays to a minimum.

1.3.7 An A-SMGCS will reduce voice communications, improve surface guidance aids and increase reliance on avionics in the cockpit to help guide the pilot to and from the runway. The ATC capability for surveillance by electronic means will also improve. Automation will play a greater role to assist in monitoring the surface operations.

1.3.8 Communications will migrate into a mix of voice and data link capabilities, with automated data communications between system components providing situation information between the users, including from the ground to the cockpit. Voice communications will continue to be used where necessary.

1.3.9 Surface guidance will include improved visual aids for automated guidance and control along the assigned route. However, for low visibility conditions, the pilot may need suitable avionics, such as a moving map, to monitor progress and compliance with the assigned route. These avionics may also be used to display surface traffic information.

1.3.10 Improved ATC surveillance will provide accurate information on the position and identity of all aircraft and vehicles operating on the movement area. This will be used to enhance the automated functions associated with conformance monitoring and conflict alert. Also, the surveillance information will be useful in refining the traffic planning functions associated with predicting taxi throughput and arrival/departure times.

1.3.11 Automated functions will include the monitoring of conformance with taxi instructions and the detection of potential conflicts and their resolution. Automation will also be used to control ground visual aids based on controller and surveillance inputs. Thus, the ground visual aids will be set up for the runway configuration in use, and runway/taxiway intersections will be controlled based on precise knowledge of the location and movement of aircraft and vehicles.

1.3.12 Surface traffic planning automation functions will be integrated with approach/departure operations. For arrivals, the sequence for each runway and stand assignment will be used to make accurate estimates of arrival times at the stands. This information will improve aircraft handling and turn-around time. For departures, engine start and push-back times can be coordinated and managed to gain optimum departure sequencing, taking into account the planned route. Also, aerodrome configuration changes will be timed and implemented more efficiently, thereby minimizing any impact on the aerodrome utilization rate.

1.3.13 Development of complex systems and the differing needs of users will require a modular development and introduction of various elements (some of which are already in place). The expected evolutionary development of A-SMGCS and the varied needs of users will mean that not all aerodromes will introduce all provisions described in this manual. Additionally, this manual can only outline steps in the continuing enhancement of aerodrome operations.

1.3.14 The technical standards implied in this manual are recognized to be the most demanding for the most critical conditions in terms of visibility, traffic density and aerodrome layout. Implementation of facilities and procedures to these levels will, therefore, not be appropriate at all aerodromes. Implementation of an A-SMGCS can only take place after an assessment of cost/benefit studies and consideration of evolving user requirements. There will be a continuing need for dialogue between the suppliers of services, the manufacturers and the users so that the operational requirements can be translated into technical requirements.

1.3.15 An A-SMGCS needs to be related to the operational conditions under which it is intended that the aerodrome should operate. Failure to provide a system appropriate to the demands placed on the aerodrome will lead to a reduced movement rate or may affect safety. It is important to recognize that complex systems are not required and are not economical at aerodromes where visibility, traffic density, aerodrome complexity and any combination of these factors do not present a problem for the ground movement of aircraft and vehicles.

Chapter 2

OPERATIONAL REQUIREMENTS

2.1 GENERAL

2.1.1 The operational requirements stated in this manual refer to the most demanding conditions and are to be applied depending upon visibility, traffic density, aerodrome layout and other local circumstances. As mentioned earlier, the visibility conditions used throughout this manual are those described in Appendix A.

2.1.2 For a particular aerodrome, an A-SMGCS is intended to mean one integrated system providing advanced surface movement guidance and control at that aerodrome. The accountability for the safety of operations associated with an A-SMGCS will ultimately lie with the service provider, the airlines and the airport authority. In this manual, the term "responsibility" applies only to the person or system and a designated role or function within an A-SMGCS.

2.1.3 Airport authorities allocate their apron areas to different control authorities. In some cases, ATC has complete jurisdiction, and in others, there is some form of apron or ramp control that exercises complete or partial jurisdiction on behalf of the airport authority. Whichever method of control is used, the level of service provided by the A-SMGCS should be consistent from the runway to the stand and vice versa.

2.1.4 In order to resolve the problem of vehicle control/segregation on a specific stand, the concept is introduced whereby the role of that stand may change from active to passive and vice versa. Hence, the use of the term "movement area" in this manual excludes passive stands, empty stands and those areas of the apron(s) which are exclusively designated to vehicle movements.

2.1.5 An A-SMGCS, as described in this manual, requires the development of an integrated human-machine interface (HMI) that will lead to a reduced workload for controllers, pilots and vehicle drivers by using computers and automation but retaining a manual control capability.

2.2 SYSTEM OBJECTIVES AND FUNCTIONS

2.2.1 In order to support optimized "gate-to-gate" operations, an A-SMGCS should be capable of assisting authorized aircraft and vehicles to manoeuvre safely and efficiently on the movement area. An A-SMGCS should support the following primary functions:

a) surveillance;

b) routing;

c) guidance; and

d) control.

Note.— Communication is considered to be an integral part of each of the primary functions.

2.2.2 In order to achieve the maximum benefits at each level of A-SMGCS implementation, a supporting planning function should be included.

2.2.3 An A-SMGCS should be capable of operating at a specified movement rate in visibility conditions down to the aerodrome visibility operational level (AVOL). When visibility conditions are reduced to below AVOL, an A-SMGCS should provide for a reduction of surface movements of aircraft and vehicles to a level acceptable for the new situation.

2.2.4 The system should integrate movements to provide complete situational information to all users, and to provide conflict prediction and resolution for aircraft and vehicle movements.

2.2.5 A-SMGCS should be modular so that the appropriate level of service can be provided to different aerodromes as well as to different areas of an aerodrome.

2.3 DIVISION OF RESPONSIBILITIES AND FUNCTIONS

Although the responsibilities and functions may vary, they should be clearly defined for all users of the system. An A-SMGCS should be designed so that the responsibilities and functions may be assigned to the following:

a) the automated system;

b) controllers;

c) pilots;

d) vehicle drivers;

e) marshallers;

f) emergency services;

g) airport authorities;

h) regulatory authorities; and

i) security services.

Note.— When using A-SMGCS, pilots remain responsible for the safety and control of aircraft.

2.4 IMPLEMENTATION-RELATED REQUIREMENTS

2.4.1 The design principle of an A-SMGCS should permit modular enhancements. The A-SMGCS at each aerodrome will comprise its own mix of modular components depending on the operational factors that are categorized in Appendix A. For example, some modules of an A-SMGCS will be required when one or more of the following conditions exist:

a) visibility condition 2, 3 or 4; and/or

b) heavy traffic density; and/or

c) complex aerodrome layout.

2.4.2 The certification of an A-SMGCS should address the total system.

Note 1.— An A-SMGCS total system includes subsystems, equipment and other components necessary for it to perform its functions, as well as operational procedures, the identification of responsibilities, management functions and system support facilities.

Note 2.— The addition of modules or the upgrading of existing modules will require an analysis to ensure that the continued validity of the original certification is not affected. Where the continued validity of the original certification cannot be assured, a new certification of the complete system will be required.

2.5 BASIC FUNCTIONAL REQUIREMENTS

Note.— The interdependency of the primary A-SMGCS functions needs to be taken into account in addressing the requirements that follow.

2.5.1 Surveillance

2.5.1.1 The surveillance function of an A-SMGCS should:

a) provide accurate position information on all movements within the movement area;

b) provide identification and labelling of authorized movements;

c) cope with moving and static aircraft and vehicles within the coverage area of the surveillance function;

d) be capable of updating data needed for the guidance and control requirements both in time and position along the route; and

e) be unaffected by operationally significant effects such as adverse weather and topographical conditions.

2.5.1.2 The operational status of all surveillance equipment should be monitored by the system, and alerts should be provided as appropriate.

2.5.1.3 All control authorities concerned should be provided with surveillance data in the required area of the aerodrome.

2.5.1.4 Within the required area of the aerodrome, surveillance should be provided up to an altitude so as to cover missed approaches and low-level helicopter operations.

2.5.1.5 Surveillance should be provided for aircraft on approach to each runway at such a distance that inbound aircraft can be integrated into an A-SMGCS operation so that aerodrome movements, including aircraft departures or aircraft crossing active runways, can be managed.

2.5.1.6 A seamless transition should be provided between the surveillance for an A-SMGCS and the surveillance of traffic in the vicinity of an aerodrome.

2.5.1.7 The A-SMGCS should detect any incursion into areas used for aircraft movement and the runway strips, and within any designated protected area as required by airport authorities. The surveillance system should also continuously indicate the position of unauthorized aircraft, vehicles and obstacles in the above areas.

2.5.1.8 For aircraft and vehicles within the areas mentioned in 2.5.1.7, the surveillance function of an A-SMGCS should continuously provide information required to detect deviations from the assigned route, with an update rate that is sufficient to ensure an adequate response of the system.

2.5.2 Routing

2.5.2.1 Either manually or automatically, the routing function of an A-SMGCS should:

a) be able to designate a route for each aircraft or vehicle within the movement area;

b) allow for a change of destination at any time;

c) allow for a change of a route;

d) be capable of meeting the needs of dense traffic at complex aerodromes; and

e) not constrain the pilot's choice of a runway exit following the landing.

2.5.2.2 In a semi-automatic mode, the routing function should also provide the control authority with advisory information on designated routes.

Note.— In a semi-automatic mode, assignment of routes is carried out by the control authority.

2.5.2.3 In an automatic mode, the routing function should also:

a) assign routes; and

b) provide adequate information to enable manual intervention in the event of a failure or at the discretion of the control authority.

2.5.2.4 When assigning routes, an A-SMGCS should:

a) minimize taxi distances in accordance with the most efficient operational configuration;

b) be interactive with the control function to minimize crossing conflicts;

c) be responsive to operational changes (e.g. runway changes, routes closed for maintenance, and temporary hazards or obstacles);

d) use standardized terminology or symbology;

e) be capable of providing routes as and when required by all authorized users; and

f) provide a means of validating routes.

2.5.3 Guidance

The guidance function of an A-SMGCS should:

a) provide guidance necessary for any authorized movement and be available for all possible route selections;

b) provide clear indications to pilots and vehicle drivers to allow them to follow their assigned routes;

c) enable all pilots and vehicle drivers to maintain situational awareness of their positions on the assigned routes;

d) be capable of accepting a change of route at any time;

e) be capable of indicating routes and areas that are either restricted or not available for use;

f) allow monitoring of the operational status of all guidance aids; and

g) provide online monitoring with alerts where guidance aids are selectively switched in response to routing and control requirements.

Note.— When visibility conditions permit a safe, orderly and expeditious flow of authorized movements, the guidance function will primarily be based on standardized ground visual aids. If expeditious flow is restricted due to reduced visibility, additional equipment or systems will be required to supplement visual aids in order to maintain flow rates.

2.5.4 Control

2.5.4.1 The control function of an A-SMGCS should:

a) have a capacity sufficient for the maximum authorized movement rate (dynamic capacity);

b) have a capacity sufficient for the aerodrome planning of requested movements for a period of up to one hour (static capacity);

c) detect conflicts and provide resolutions;

d) be able to provide longitudinal spacing to predetermined values of:

1) speeds;

2) relative directions;

3) aircraft dimensions;

4) jet blast effects;

5) human and system response times; and

6) deceleration performances;

e) provide alerts for incursions onto runways and activate protection devices (e.g. stop bars or alarms);

f) provide alerts for incursions onto taxiways and activate protection devices (e.g. stop bars or alarms);

g) provide alerts for incursions into critical and sensitive areas established for radionavigation aids;

h) provide alerts for incursions into emergency areas;

i) be capable of incorporating computer-aided management tools;

j) keep controllers, pilots and vehicle drivers in the decision loop;

k) control movements within a speed range so as to cover the operations in all required situations, taking into account the type of movement;

l) be capable of allowing operations to continue in all visibility conditions down to the AVOL; and

m) be capable of allocating priorities to control activities.

2.5.4.2 The control function of an A-SMGCS should also provide for:

a) sequencing of aircraft after landing, or of departing aircraft, to ensure minimum delay and maximum utilization of the available capacity of the aerodrome;

b) segregation of support and maintenance vehicles from operational activities as necessary;

c) spacing between aerodrome movements according to the prescribed minima, taking into account:

1) wake turbulence;

2) jet blast and propeller/rotor wash;

3) aircraft dimensions; and

4) different locations and layouts (runway, taxiway, apron or aircraft stand);

d) separation of movements from obstacles; and

e) separation with a prescribed minimum of all aircraft from an aircraft isolated for security reasons (Annex 14 to the Convention on International Civil Aviation — *Aerodromes,* Volume I, Chapter 3).

2.5.4.3 The following short-term alerts should be provided by the A-SMGCS within enough time to enable the appropriate immediate action:

a) short-term conflict alert: whereby an alert is triggered when the predicted spacing will be below preset/predefined minima;

b) area penetration alert: whereby an alert is triggered when a movement likely to enter a critical or restricted area is detected;

c) deviation alert: whereby an alert is triggered when the computed deviation will be more than the preset/predefined maximum deviation;

d) runway incursion alert: whereby an alert is triggered when a movement likely to enter an active runway (runway strip) is detected; and

e) taxiway (or an inactive runway being used as a taxiway) or apron incursion alert: whereby an alert is triggered when a movement likely to enter a taxiway or apron in use, which does not belong to its assigned route, is detected.

2.5.4.4 Distinctive medium-term alerts should be provided well in advance to enable the appropriate remedial action to be taken with respect to:

a) conflict prediction;

b) conflict detection; and

c) conflict resolution.

2.5.4.5 Once a conflict has been detected, an A-SMGCS should either automatically resolve the conflict or, on request from the controller, provide the most suitable solution.

2.6 SUPPLEMENTARY REQUIREMENTS

2.6.1 Global risk factor

The introduction of an A-SMGCS should not result in an overall level of risk in excess of the probability of one fatal accident per 10^7 operations.

2.6.2 Aircraft types

An A-SMGCS should support operations involving all aircraft types and be capable of adaptation to cater for future aircraft types.

2.6.3 Vehicles

2.6.3.1 An A-SMGCS should be capable of being used by appropriately equipped vehicles operating within the movement area.

2.6.3.2 Any authorized vehicle intended to be used on the aerodrome in the vicinity of the manoeuvring area should be equipped to inform an A-SMGCS of its position.

2.6.4 Speeds and orientation

The system should be capable of supporting operations of aircraft and vehicles within the following parameters:

a) minimum and maximum speeds for aircraft on final approach, missed approach and runways;

b) minimum and maximum speeds for aircraft on taxiways;

c) minimum and maximum speeds for vehicles; and

d) any heading.

2.6.5 Susceptibility

The system should not be affected by:

a) radio interference, including that produced by navigation, telecommunications and radar facilities (including airborne equipment);

b) signal reflections and shadowing caused by aircraft, vehicles, buildings, snow banks or other raised obstacles (fixed or temporary) in or near the aerodrome; and

c) meteorological conditions or any state of the aerodrome resulting from adverse weather in which operations would otherwise be possible.

2.6.6 Reference system

2.6.6.1 An A-SMGCS should be referenced to the World Geodetic System — 1984 (WGS-84).

2.6.6.2 A common reference point on aircraft and vehicles should be used in A-SMGCS.

2.6.7 Planning

2.6.7.1 In order to support the primary functions (surveillance, routing, guidance and control), the planning facilities of an A-SMGCS should provide for:

a) strategic planning which will indicate the predicted traffic situation for chosen times in excess of 20 minutes in advance;

b) pre-tactical planning which will indicate the predicted traffic situation at a chosen time up to 20 minutes in advance; and

c) tactical planning which will indicate the present traffic situation.

2.6.7.2 Planning facilities should include methods of predicting an aerodrome capacity and indication of start-up times for traffic to meet this capacity.

Note 1.— The capacity assessment is to be based on factors such as weather conditions, serviceability of equipment, and closure of sections of the movement area.

Note 2.— Additional elements to be included in the capacity assessment are the operational activity needs of the movement area, such as surface inspections, friction measurement, and snow clearance.

Note 3.— The implementation of an A-SMGCS requires the designation of routes that ensure the safe and efficient movement of aircraft and vehicles. The route issued for any movement will be dependent on strategic, pre-tactical and tactical considerations that will be addressed within the overall planning function.

2.6.8 Recording

2.6.8.1 Selected data on the communications control activity and display information should be recorded for accident and incident investigation.

2.6.8.2 There should be a function to provide direct replay of recorded data within the operational system, as part of the requirement for immediate checking of suspect equipment and initial incident investigation.

2.6.9 System failures

2.6.9.1 Equipment that shows control data should be both fail-safe and fail-soft.

Note.— The term "fail-safe" in this context means that sufficient redundancy is provided to carry data to the display equipment to permit some components of the equipment to fail without any resultant loss of data displayed. The term "fail-soft" means that the system is so designed that, even if equipment fails to the extent that loss of some data occurs, sufficient data remain on the display to enable the controller to continue operations.

2.6.9.2 In case of a failure of an element of an A-SMGCS, the effect should be such that the status is always in the "safe" condition.

2.6.9.3 All critical elements of the system should be provided with timely audio and visual indications of failure.

2.6.9.4 An A-SMGCS should be self-restartable. The recovery time should be a few seconds. The restart of an A-SMGCS should include the restoration of pertinent information on actual traffic and system performance.

2.6.10 Aerodrome considerations

An A-SMGCS should be capable of accommodating any change in the layout of the aerodrome (runways, taxiways and aprons).

2.6.11 Pilot considerations

Pilots should be provided with the following:

a) information on location and direction at all times;

b) continuous guidance and control during:

   1) the landing roll-out;

   2) taxiing to the parking position and from the parking position to the runway-holding position;

   3) lining up for an appointed take-off position; and

   4) the take-off roll;

c) indication of the route to be followed, including changes in direction and indication of stops;

d) guidance in parking, docking and holding areas;

e) indication of spacing from preceding aircraft, including speed adjustments;

f) indication of spacing from all aircraft, vehicles and obstacles in visibility condition 4;

g) indication of the required sequencing;

h) information to prevent the effects of jet blast and propeller/rotor wash;

i) identification of areas to be avoided;

j) information to prevent collision with other aircraft, vehicles and known obstacles;

k) information on system failures affecting safety;

l) the location of active runways;

m) alert of incursions onto runways and taxiways; and

n) the extent of critical and sensitive areas.

Note.— Most of the foregoing requirements may be satisfied by using ground visual aids.

2.6.12 Vehicle driver considerations

2.6.12.1 Vehicle drivers should be provided with the following:

a) information on location and direction at all times;

b) indication of the route to be followed;

c) guidance along the route being followed or guidance to remain within designated areas;

d) information, and control when and where appropriate, to prevent collision with aircraft, vehicles and known obstacles; and

e) alert of incursions into unauthorized areas.

2.6.12.2 In addition to 2.6.12.1, the drivers of emergency and operational vehicles should be provided with:

a) the capability to locate the site of an emergency within the displayed range of the system; and

b) information on special priority routes.

Note.— Most of the foregoing requirements may be satisfied by using ground visual aids.

2.6.13 Apron management considerations

The following information should be available to the apron management services:

a) information on the identity, position and progress of aircraft, including aircraft under tow;

b) information on the identity, position and progress of vehicles whose movements might conflict with aircraft movements;

c) information on the presence of obstacles or other hazards;

d) information on the operational status of system elements; and

e) information on facilities appropriate to the control to be exercised.

2.6.14 Automation

2.6.14.1 Where automation is available, the automated systems should demonstrate an acceptable level of HMI efficiency.

2.6.14.2 The design of an A-SMGCS should make it possible to make a distinction between the following system elements and functions:

a) system assistance in the decision-making process;

b) system advice on the decisions taken; and

c) system decisions provided directly to the users.

2.6.14.3 Automated guidance should not be used by the system if aircraft control, conflict detection and conflict alert resolution are not available.

2.6.14.4 If the system integrity degrades, the system should automatically alert all users and have the capability to transfer automated functions to the controllers in a safe and easy way.

2.6.14.5 Without automation, it may not be possible to meet some operational requirements. Automation of functions can be applied to various parts of an A-SMGCS such as:

a) identification of aircraft and vehicles;

b) tracking and labelling of targets;

c) route assignment;

d) guidance and control;

e) runway incursion detection;

f) unauthorized intruder detection;

g) conflict prediction;

h) conflict detection;

i) conflict resolution;

j) alert indication;

k) indication of appropriate brightness setting for visual aids; and

l) stand allocation.

Note.— Automation validation processes are expected to encompass all environmental and failure conditions including a reversion to manual control.

2.6.15 Human-machine interface (HMI)

2.6.15.1 The operation of an A-SMGCS should not interfere with other ATC responsibilities.

2.6.15.2 The human-machine interface with an A-SMGCS should:

a) maintain a balance between the human and the machine functions;

b) permit the human to retain the power to make decisions as to those functions for which the human is responsible; and

c) provide for a balanced mix of visual, audio and tactile inputs and responses.

2.6.15.3 Input devices for the controllers should be functionally simple — involving the controllers in a minimum number of input actions.

2.6.15.4 It should be possible to view displays and indicators in all ambient light levels typical of an aerodrome control tower environment.

2.6.15.5 Account should be taken of the ability of the flight crew and vehicle drivers to respond to the guidance and control indications of the system.

2.6.15.6 The system should provide pilots and vehicle drivers with essential routing, guidance and control data in a standardized form that at all times is conspicuous, legible, comprehensible and credible. Guidance should be implemented in such a way as to minimize the pilots'/vehicle drivers' head down time, while maximizing the use of visual cues.

2.6.15.7 For control staff, the system should have interfaces that allow them to manage the routing, guidance and control functions in a safe and efficient manner.

2.6.16 Interfaces

2.6.16.1 In order for all parties concerned to fully benefit from an A-SMGCS, the system should be capable of interfacing with the following:

a) air traffic management (ATM), including:

   1) arrival and departure management;

   2) arrival and departure coordination;

   3) optimized start-up sequence and times;

   4) optimized push-back sequence and times; and

   5) integrated initial flight plan processing system, central flow management unit, etc.;

b) aerodrome management systems;

c) existing and future ATS systems;

d) meteorological systems;

e) visual aids;

f) existing and future avionics;

g) aerodrome handling systems;

h) aircraft operators;

i) emergency authorities;

j) police/security authorities; and

k) other customers or users.

2.6.16.2 The data interchange between systems should be made in a standardized format.

2.6.16.3 An A-SMGCS should enable controllers, pilots and vehicle drivers to interface and function efficiently. These operators should also be capable of interfacing with other systems.

2.7 SYSTEM REQUIREMENTS

2.7.1 Accuracy

2.7.1.1 In specifying the positional accuracy parameters for an A-SMGCS, the requirements for the primary functions and their interdependencies should be considered.

2.7.1.2 For the surveillance function, the allowable error in the reported position should be consistent with the requirements set by the guidance and control functions.

2.7.1.3 For the guidance function, the allowable positional errors should be similar for visual and electronic taxi guidance. However, in visibility conditions where electronic guidance is required in specifying the allowable errors, taxiway widths and aircraft main gear wheel tracks should be considered.

2.7.2 Update rate

Where appropriate, the update rate of an A-SMGCS module should be adequate for the required operational performance.

2.7.3 Integrity

2.7.3.1 The system design should preclude failures that result in erroneous data for operationally significant time periods.

2.7.3.2 The system should have the ability to provide continuous validation of data and timely alerts to the user when the system must not be used for the intended operation. The validity of data should be assessed by the system in accordance with the assigned priority given to these data.

2.7.3.3 Validation of operationally significant data should be timely and consistent with human perception and/or response time.

2.7.4 Availability and continuity

2.7.4.1 The availability of an A-SMGCS should be sufficient to support the safe, orderly and expeditious flow of traffic on the movement area of an aerodrome down to its AVOL.

2.7.4.2 An A-SMGCS should provide a continuous service for all areas determined by the competent authorities. Any unscheduled break in operations should be sufficiently short or rare so as not to affect the safety of aircraft using the system.

2.7.4.3 Monitoring of the performance of an A-SMGCS should be provided so that operationally significant failures are detected and remedial action is initiated to restore the service or provide a reduced level of service.

2.7.4.4 Automatic positive indication of the status of the system or any operationally significant failure should be given to any aircraft, vehicle or control facility that may be affected.

2.7.5 Reliability

2.7.5.1 An A-SMGCS should be designed with an appropriate level of redundancy and fault tolerance in accordance with the safety requirements. A self-checking system with failure alerts should be included in the system design.

2.7.5.2 A failure of equipment should not cause:

a) a reduction in safety (fail-soft); and

b) the loss of basic functions.

2.7.5.3 The system should allow for a reversion to adequate back-up procedures if failures in excess of the operationally significant period occur. Operationally significant failures in the system should be clearly indicated to the control authority and any affected user.

Chapter 3

GUIDANCE ON THE APPLICATION OF THE OPERATIONAL AND PERFORMANCE REQUIREMENTS

3.1 SYSTEM OBJECTIVES AND FUNCTIONS

The main objectives of an A-SMGCS (as stated in 2.2) may be achieved by the following measures:

a) enhancing the surveillance function to ensure that controllers receive all necessary information on all aircraft and vehicles on the movement area (including their identification) down to the AVOL;

b) enhancing the situation awareness of pilots, particularly in low visibility conditions — when the "see and be seen" principle is not applicable;

c) developing routing facilities in order to make full use of aerodrome capacity. This will require the provision of a tactical planning tool;

d) providing clear indications of assigned routes to pilots and vehicle drivers in the movement area so that they can follow the assigned routes down to the AVOL; and

e) improving the control of runway and taxiing operations by implementing incursion alerts and tools to predict, detect and resolve conflicts.

3.2 DIVISION OF RESPONSIBILITIES AND FUNCTIONS

3.2.1 General

3.2.1.1 The consideration of assigning responsibilities within the operation of A-SMGCS will be a major factor in the overall design of such systems. The design of A-SMGCS should not be constrained by existing allocations of responsibility. It should be recognized that changes may be required to make use of new technology and operational concepts. New elements will be introduced as systems become more capable, and the correct operation of certain functions will involve the responsibilities of manufacturers and producers of software. A thorough and ongoing review of the present division of responsibility is required to see more clearly how new concepts will affect existing arrangements.

3.2.1.2 The implementation of an A-SMGCS and its associated procedures enables the introduction of a high level of automation. This automation offers the possibility of "system" management of safety-related tasks that are normally performed by humans. Where there is a safety risk associated with the role and responsibility afforded to system functionality, a full risk assessment should be carried out.

3.2.1.3 It is a requirement for the design and use of an A-SMGCS that the responsibilities for the safe operation of the system be fully assigned. This assignment of responsibilities should be related to the operational conditions. In low visibility conditions, particular attention should be paid to this aspect of the design. Some of the principal areas of responsibility are:

a) the pilot of an aircraft is ultimately responsible for the safety of the aircraft and will always remain in control of the aircraft;

b) the controller concerned will have the primary responsibility to operate and interpret the A-SMGCS;

c) a suitable A-SMGCS may be approved to automatically provide specific functions, such as identification, guidance and conflict detection, to controllers, pilots and vehicle drivers; and

d) the pilot or vehicle driver will be responsible to respond to an A-SMGCS instruction or alert, unless specifically instructed otherwise by the controller.

3.2.1.4 Conflict detection is an example of a responsibility within A-SMGCS which may be delegated in some circumstances to an automated system. The strategy for dealing with any conflict must be clearly defined under all circumstances. The proximity of two objects that is deemed to constitute a conflict will be dependent on several parameters (e.g. distance, speed and location).

3.2.2 Responsibilities

3.2.2.1 The area of responsibility for ATC on an aerodrome is normally the manoeuvring area. Services on the aerodrome aprons are known as apron management services. Some States authorize a separate apron management unit, while in other States, ATC provides apron management services.

3.2.2.2 Those responsible for operations on the aerodrome surface can be broadly categorized into five groups, each with distinct functions: aerodrome management, apron management, ATC, pilots and vehicle drivers.

3.2.2.3 Personnel monitoring and operating the A-SMGCS equipment will have some responsibility for ensuring that it functions correctly; however, human operators can have no responsibility for automated functions for which they have no input.

3.2.2.4 Primary responsibility for the tactical operation of an A-SMGCS will be vested in the controller through the A-SMGCS, which may include:

a) guidance being provided by the system;

b) routing as assigned by the control authority;

c) conflict detection by the system and/or the controller; and

d) conflict resolution involving cooperation between the system, controller, pilot and vehicle driver.

3.2.2.5 Vehicle drivers must comply with aerodrome regulations, the A-SMGCS, and ATC instructions. They are always responsible for exercising due care and attention so as to avoid collisions between their vehicles and aircraft and other related hazards. Vehicle drivers should be provided with the training necessary for them to understand their duties and to permit them to comply with aerodrome, A-SMGCS and ATC procedures.

3.2.2.6 Under the conditions envisaged for the operation of an A-SMGCS, the system and its operators will be required to accept a high level of responsibility for spacing between aircraft. There will still be options for the pilot to maintain visual spacing under some circumstances, but there will also be operational conditions when pilots will not be able to see conflicting traffic and obstructions.

3.2.2.7 The nature of the conditions under which an A-SMGCS will operate requires that the pilot rely on the guidance and control that the system is providing. This guidance and control needs to extend from the runway to the parking stand and vice versa. The areas used by service vehicles which are not participating in the A-SMGCS will be strictly segregated from areas used for aircraft movements. Additionally, with the highly complex working environment and sophisticated HMI required for an A-SMGCS, training is necessary, with a licensing requirement, to ensure the continued competence of operating staff. Responsibility for control needs to be allocated in such a way that the same level of service is provided to aircraft and vehicles throughout the movement area.

3.2.2.8 ATC controls both aircraft and vehicles on the manoeuvring areas, giving aircraft priority. To do this, ATC must use standardized radiotelephony communications with regard to phraseology, procedures and language. In lower visibility conditions, when the responsibility for avoidance of collisions on the ground becomes increasingly that of the ATC unit, controllers may have to restrict the number of aircraft and/or vehicle movements on the manoeuvring area.

3.2.2.9 To enable ATC to carry out the above responsibilities, an A-SMGCS should be designed to at least assist in the prevention of:

a) incursions of aircraft and vehicles onto runways and taxiways in all visibility conditions; and

b) collisions between:

   1) aircraft operating on the manoeuvring area in all visibility conditions;

   2) aircraft and vehicles operating on the manoeuvring area in all visibility conditions;

   3) aircraft operating on the manoeuvring area and obstructions on that area in all visibility conditions;

   4) vehicles operating on the manoeuvring area in visibility condition 4; and

   5) vehicles operating on the manoeuvring area and obstructions on that area in visibility condition 4.

3.2.2.10 To enable the apron management unit to carry out its responsibilities, an A-SMGCS should be designed to assist on the apron in the prevention of:

a) incursions of aircraft, vehicles and unauthorized personnel onto designated areas and routes in all visibility conditions; and

b) collisions in visibility conditions 3 and 4 between:

   1) aircraft;

   2) aircraft and vehicles;

   3) aircraft and obstructions;

   4) controlled vehicles; and

   5) controlled vehicles and obstructions.

3.2.2.11 An interface should be provided between the apron management services and the aerodrome control services. The apron management services may be responsible for aircraft stand allocation and the dissemination of movement information to aircraft operators and could achieve this by monitoring ATC frequencies and updating basic information on aircraft arrival, landing and take-off times.

3.2.2.12 The aerodrome management is responsible for the regular inspection of the manoeuvring area and aprons of the airport to ensure that all lighting, markings and signage are kept serviceable and not obscured by contaminants such as snow and ice. In addition, aerodrome management must designate standard taxi routes and vehicle operating lanes, control access to the movement area, and train and motivate the aerodrome personnel.

3.3 IMPLEMENTATION-RELATED REQUIREMENTS

3.3.1 Evolutionary implementation

3.3.1.1 It is not envisaged that the existence of operational requirements for an A-SMGCS will immediately result in a current SMGCS becoming obsolete. The strategy that underlies the requirements for an A-SMGCS assumes that the development and implementation of the system will proceed at a pace that is primarily determined by operational and economic considerations at each individual aerodrome. Appendix B lists criteria for determining A-SMGCS implementation levels.

3.3.1.2 In general, an A-SMGCS should evolve from the installed SMGCS by progressive enhancements to existing ground equipment to match the desired level of operations. The extent to which this should be done at an individual aerodrome should be consistent with the levels of traffic, the operating conditions and the configuration at that aerodrome. Components can be added to an existing SMGCS when traffic requirements justify an expansion. The A-SMGCS solution for an aerodrome, therefore, will be matched to its specific operational requirements and physical characteristics. This evolutionary process is illustrated in Appendix C.

3.3.2 Standardization and certification

3.3.2.1 A certification process, which is universally applied, is in place for aircraft, their operations and the avionics systems installed on board. It has agreed regulatory objectives and common procedures. This process is not normally adopted for ATS systems. Ground system service providers often specify the system taking into account current Standards and Recommended Practices (SARPs) but will commission the system without independently agreed and harmonized safety objectives. With the implementation of an A-SMGCS, there is a need to adopt a certification process that addresses the safety aspects of the system or services in total. This approach is proposed for all new ATS systems where there is an integration of new technology in the airborne and ground elements, and where there is utilization of advanced automation techniques.

3.3.2.2 System certification would consider, and provide proof of compliance with, safety requirements for each functional domain within an A-SMGCS, and safety objectives for the procedures. Furthermore, safety and quality management infrastructures within the organizations providing or using an A-SMGCS will need to demonstrate adequacy and be subject to continuous compliance monitoring. The meeting of the certification criteria should lead to the granting of an approval for operational use of the A-SMGCS and for participating aircraft operators.

3.3.2.3 The use of the safety case methodology is one means of demonstrating the safety of an A-SMGCS. This method provides reasoned arguments for the acceptability of the safety of the system. It also provides mechanisms whereby the safety of operations is continuously monitored and, if necessary, improved.

3.3.2.4 Certification should be a team effort. The team could comprise the A-SMGCS provider, the ATS provider, the aerodrome authority, the participating aircraft operators, and the certification authorities. Certification authorities should preferably be autonomous.

3.3.2.5 International standards and specifications should be used in the design of an A-SMGCS to enable interoperability and open systems modularity. Interoperability should ensure that aircraft systems are compatible with any A-SMGCS throughout the world.

3.3.2.6 For a component to comply with interoperability requirements, industry standards are required. These standards would define the minimum functional and performance requirements. Substantiation of the interoperability requirements would also require a safety analysis of the functional performance of the component to determine that no additional hazards are introduced. This would lead to the issuance of a type approval for that component and would alleviate the need to re-certify all or a major part of an A-SMGCS.

3.3.2.7 One aspect that should be considered when modifying a part of a certified system would be the impact of the modification on the operational use of the system. For example, before exchanging an A-SMGCS component of one brand with another brand, it must be demonstrated that the new component has the same functional characteristics as the original and that no safety requirements are compromised.

3.3.3 Introduction of new technologies

3.3.3.1 In general, the introduction of new technology for A-SMGCS should conform with international standards. The implementation of new technologies should be subject to the approval of the competent authority concerned.

3.3.3.2 For security and maintenance reasons, it is highly desirable that all ground-based modules of an A-SMGCS are sited within the aerodrome boundary.

3.3.3.3 While it is beyond the scope of an operational requirement to specify technological solutions, there are certain factors that affect the efficiency of operations that need to be taken into account when considering the technology to be used and the impact it may have on system performance. The following are the principal considerations:

a) surveillance:

   1) at present, aerodrome control procedures require visual confirmation to maintain safety levels. In reduced visibility conditions this ability is impaired. Surveillance aids may be upgraded to provide target identification and classification; and

   2) surveillance tools may provide data for conflict prediction, detection and resolution;

b) communications:

   1) radiotelephony should be retained for use at all aerodromes as the primary means to issue tactical instructions; and

   2) data link may be used to supplement radiotelephony. It will be particularly useful to provide clearances and routings that are not subject to time critical transmission and that do not require instantaneous action. The format of data link messages and particularly the actual display on the flight deck of such messages require standardization. There is an important distinction between acknowledging the receipt of a data link message and actually understanding its meaning. To initiate free text data link messages from the flight deck may cause disproportionately high workloads; and

c) guidance and control:

   1) current SMGCS already provide visual references as well as lighting, markings and signage. In the medium term, these references may be further enhanced by switched centre line and stop bar lights. In conditions of great complexity or reduced visibility, additional facilities may be required such as:

      i) electronic displays;

      ii) enhanced vision systems; and

      iii) satellite-derived data; and

   2) whatever precise guidance is provided to aircraft on taxiways and aprons — whether by enhanced lighting or by more sophisticated techniques — the command of the aircraft remains with the pilot.

3.3.3.4 It will be important to achieve total international standardization of:

a) visual guidance and aeronautical ground lighting systems;

b) avionics display formats;

c) enhanced vision systems; and

d) non-visual guidance systems.

3.3.3.5 For wide-body aircraft, the large area ahead of the aircraft that is obscured by the cockpit cut-off results in increased intensities being required to enable an adequate pattern of taxiway lights to be seen when the RVR is less than 75 m. Annex 14, Volume I, contains details of the minimum light intensities needed for different values of AVOL.

3.3.3.6 An A-SMGCS may be used to increase the capacity of high-density and/or complex aerodromes by improving the planning and monitoring of ground movement in all weather conditions, or by improving guidance, while maintaining safety.

3.3.3.7 An A-SMGCS requires certain data that can only be provided by external sources. Essentially this is anything that could have an operational impact on the A-SMGCS and may include, but is not exclusive to, the following:

a) aerodrome information:

   1) physical characteristics/layout;

   2) runway(s) in use, including whether the runway is exclusively used for landing or departing traffic;

   3) the demarcation of safety-significant areas, e.g. runway-holding positions, and navigational aid protection areas;

   4) runway and taxiway availability; and

   5) work in progress;

b) meteorological information:

   1) the prevailing and expected meteorological conditions at the aerodrome;

   2) visibility/RVR, including, where applicable, on aprons and taxiways;

   3) ceiling;

   4) wind speed and direction;

   5) atmospheric pressure; and

   6) temperature and dewpoint; and

c) flight operational information:

   1) AVOL;

   2) wake turbulence; and

   3) standard instrument departure (SID) and standard instrument arrival (STAR) routes, including noise preferential routes.

3.3.3.8 Prior to updating an A-SMGCS, new data should be validated. For example, new data should be checked for inconsistency and unlikely variation from previous data, and for being out of tolerance.

3.3.3.9 All data provided by an A-SMGCS should be given a date and time of issue and period of validity. The A-SMGCS function or element, according to the data's use, may determine the validity of the data. Information received from a source external to the A-SMGCS that does not have a date, time and period of validity should be regarded as invalid. Old and invalid data should not be used.

3.4 BASIC FUNCTIONAL REQUIREMENTS

Note.— The functional operation of an A-SMGCS as a whole will consider the interdependency of the functions. Interdependency may change depending on the concept of an A-SMGCS whether part or all of a functionality will be served by another function.

3.4.1 Surveillance

General

3.4.1.1 Surveillance is an essential element of any SMGCS as well as any A-SMGCS. A combination of visual surveillance, SMR and radiotelephony is currently used by controllers to monitor movements. The monitoring of other aircraft and vehicles is also a significant function performed by pilots and vehicle drivers. As visibility is gradually reduced, the ability of controllers and pilots to carry out visual surveillance becomes increasingly impaired. Problems for controllers become significant when the manoeuvring area cannot be adequately observed from the control tower. When the visibility falls below 400 m, the ability of pilots and vehicle drivers to visually observe becomes seriously impaired.

3.4.1.2 Improvement of the surveillance function to overcome the above-mentioned problems down to the AVOL is one of the key requirements of an A-SMGCS. The surveillance function therefore should provide identification of, and accurate positional information on, all movements on the movement area including the runway strip.

3.4.1.3 It is expected that more than one type of sensor and a data fusion unit may be needed to meet the requirements specified below.

Reliability

3.4.1.4 In order to determine the reliability of the A-SMGCS surveillance function, the following parameters should be considered in the specification of surveillance equipment:

a) probability of detection (PD) — the probability that an aircraft, vehicle or object is detected and displayed;

b) probability of false detection (PFD) — the probability that anything other than an aircraft, vehicle or object is detected and displayed;

c) probability of identification (PID) — the probability that the correct identity of an aircraft, vehicle or object is displayed; and

d) probability of false identification (PFID) — the probability that the displayed identity of the aircraft, vehicle or object is not correct.

Coverage

3.4.1.5 The surveillance function should, depending on the procedures in use, be capable of determining the position and identification of aircraft and vehicles on the movement area, including obstacle-free zones and protected areas.

3.4.1.6 The surveillance coverage area requirements should apply to operations in all visibility conditions.

3.4.1.7 The vertical surveillance coverage of an A-SMGCS should include all relevant non-surface operations that take place at the aerodrome.

3.4.1.8 Information, including call sign and estimated time of arrival (ETA), on inbound aircraft should be provided at least 5 minutes before touchdown or not less than 10 NM from the aerodrome. The source of this information may not be part of the A-SMGCS. The information may be provided by an external system.

Identification

3.4.1.9 The surveillance function should, within the specified coverage areas, identify and provide the call sign of each aircraft and vehicle and correlate the call sign with its position. The type of aircraft, including any variety, should be identified and verified. The position of obstacles should be appropriately marked.

Longitudinal accuracy

3.4.1.10 The accuracy requirement is based on the effect of the surveillance accuracy on the ability to detect loss of required spacing and potential traffic conflicts or runway incursions. Two scenarios were analysed: i) a runway incursion where the aircraft crosses the runway-holding position; and ii) the loss of longitudinal spacing between two aircraft. The runway incursion scenario was designed to determine the warning time required of the surveillance system to the potential incursion, and to prevent the aircraft from proceeding onto the runway (see Figure 3-1). The geometry depicted is for airports where the runway-holding position is 75 m from the runway centre line.

3.4.1.11 Based on this scenario and a sensitivity analysis of the effect of accuracy, it was determined that 20 m would allow time (with some margin) for detection of an incursion and stopping of the aircraft prior to entering the runway. This is based on the pilot being provided with conflict information directly.

3.4.1.12 In the case where an air traffic controller must be alerted and then must issue instructions to the pilot, all accuracy values result in an excessive time delay, resulting in an inability to prevent the aircraft from entering the runway. However, in general, a surveillance accuracy better than 20 m can result in significant improvements in system

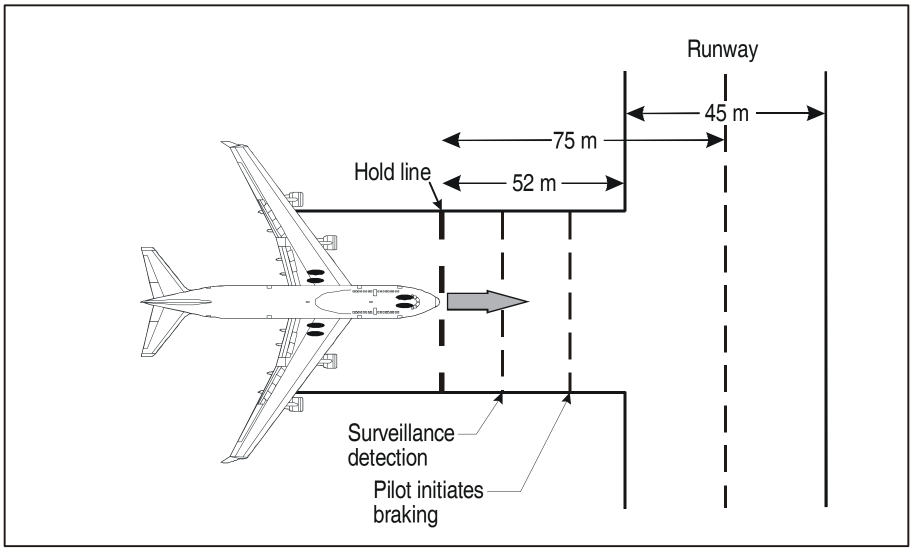


Figure 3-1. Runway incursion detection scenario

performance and allow more time for reaction to avoid a conflict. The longitudinal accuracy is recommended to be 6 m.

Lateral accuracy

3.4.1.13 The required position accuracy is based on the most demanding ICAO provisions to ensure a 3 m minimum clearance between an aircraft on the stand and any adjacent building, aircraft on another stand and other objects.

Data update rate and latency

3.4.1.14 An update rate of one second is required in order to minimize time delays in detecting a loss of required spacing and potential conflicts. With spacings and time intervals being so short on the aerodrome, minimizing this time is critical.

3.4.1.15 A limit on the variation in the update rate is necessary primarily for Human Factors reasons. If the update rate varied significantly, the rate of movement of targets would make it difficult to use judgement to determine the motion of an aircraft or vehicle. Minimizing this improves the confidence of the air traffic controllers and pilots in the reliability of the information presented to them. Ten per cent is a suitable limitation on this variation.

3.4.1.16 For data latency, one second was chosen as a reasonable upper value for the time between when the target position is determined and its use in detecting loss of spacing or conflicts.

3.4.2 Routing

3.4.2.1 A routing function should enhance efficiency, particularly at complex aerodromes. In these situations, and when traffic density is heavy, some form of routing function automation may be needed.

Coverage

3.4.2.2 The routing function should be capable of providing routing information for aircraft and vehicles on the movement area and, where necessary, other areas used by vehicles.

3.4.2.3 The routing function should provide an optimized route for each participating aircraft and vehicle. It should consider the overall time for an aircraft or vehicle to complete the route in all visibility conditions.

3.4.2.4 The routing function should optimize the traffic flow of aircraft and vehicle surface movements, including aircraft under tow, with respect to:

a) reducing delay — when planning a route, an effort should be made to permit an aircraft to meet its assigned take-off time or reach its allocated gate on time;

b) potential conflict — the wing-tip to wing-tip spacing between certain types of aircraft on parallel taxiways should be taken into account;

c) longitudinal spacing when visibility becomes a factor, including jet blast and propeller/rotor wash;

d) obstructed, unavailable or temporarily closed parts of the movement area; and

e) taxi speeds (to reduce braking and acceleration, and fuel burn).

3.4.2.5 The routing function should be able to handle predefined or user-defined intermediate waypoints (e.g. routing through de-icing stations).

3.4.2.6 An alternative route should always be available on request.

3.4.2.7 By human-initiated means, or as a result of a conflict, it should be possible to immediately cancel or change an existing and used route. In the event that a route is cancelled, a new route to continue should be provided.

Time to process route requests

3.4.2.8 To allow one second each for processing and transmission means that the route would be available to the pilot within a few seconds (including controller response time), which should not have a significant impact on operations provided that the route is determined prior to the movement.

3.4.2.9 The processing capacity is related to how many routes can be requested at any one time. The assumption made is that the route request process is random; therefore, over any one-second period, only a small number of routes could be requested. The largest demand will be when there is a large number of scheduled departures closely spaced in time.

3.4.3 Guidance

General

3.4.3.1 When visibility conditions permit a safe, orderly and expeditious flow of authorized movements, the guidance function will primarily be based on standardized ground visual aids including lighting, markings and signage.

3.4.3.2 When visibility conditions are sufficient for the pilot to taxi by visual guidance only, but the sole use of visual guidance restricts the expeditious flow of authorized movements, additional equipment or systems may be needed to support the guidance function.

3.4.3.3 When visibility conditions are insufficient for the pilot to taxi by visual guidance only, the aerodrome itself, as well as aircraft manoeuvring on the movement area and authorized vehicles, should be appropriately equipped to comply with the guidance function (when operations in these visibility conditions are permitted).

3.4.3.4 Once a route has been assigned, the pilot or vehicle driver requires adequate information to follow that route. Guidance aids indicate where on the taxiway or apron the aircraft or vehicle can be manoeuvred safely. Switched centre line lights and/or addressable signs enable routes to be uniquely designated.

Reliability

3.4.3.5 The following parameters should be considered in the specification of guidance reliability requirements:

a) probability of actuation — the probability that the guidance aid will respond correctly to the command issued; and

b) probability of false actuation — the probability of unsolicited actuation of a guidance aid.

Coverage

3.4.3.6 As a minimum, guidance should be provided on the airport movement area.

3.4.3.7 The following phases of a flight should be considered in the determination of the A-SMGCS coverage requirement:

a) arrivals:

1) landing flare and landing roll begins;

2) high speed taxi;

3) landing roll ends, taxi begins or, for a rapid exit taxiway, high speed taxi ends, taxi begins;

4) taxi ends, stand taxilane begins;

5) stand taxilane ends, stand begins (empty stand becomes active);

6) stand ends, docking begins; and

7) stand becomes passive;

b) departures:

1) passive stand becomes active;

2) stand taxilane begins (stand becomes empty);

3) stand taxilane ends, taxi begins;

4) taxi ends, take-off roll begins; and

5) take-off roll ends; and

c) apron movements, such as towing, and maintenance activities.

Visual aids

3.4.3.8 The current provisions for visual aids and other guidance provided are adequate for most aerodrome operations. With the possible exception of visibility condition 4, additional equipment to that specified in Annex 14 should not be required.

3.4.3.9 Annex 14 contains photometric requirements for taxi guidance visual aids, including taxiway centre line lighting, runway and taxiway intersection guard bars, and addressable signs, that are intended to support A-SMGCS operations.

Timing

3.4.3.10 When using a speed of 55 km/h (30 kt), the distance covered by an aircraft or vehicle in two seconds is approximately 30 m, which is the normal distance in straight sections between two centre line lights. Two seconds should then be the maximum time to activate the on/off commands when guiding aircraft or vehicles with centre line lights.

Failure of visual aids

3.4.3.11 In the event of a failure (other than a total power failure) of an automatic visual aids management system, the A-SMGCS should be designed to switch on all the runway guard bars at runway access points, and switch off all taxiway centre line lights and intermediate stop bars. Manual selection and de-selection of the taxi guidance visual aids should be provided.

Taxiway centre line light parameters

3.4.3.12 *Fixed block lights* — The length is established by longitudinal spacing between initial and final block stop bars. For safety reasons, one block should be left free between aircraft, although this can limit taxiway capacity.

3.4.3.13 *Variable block lights* — The length of the block in front of aircraft may vary according to the visual range from two to six switched-on lights. Depending on the visual range, up to three lights may be left switched off between the intersection of the cockpit cut-off area with the taxiway centre line and the first switched-on centre line light in order to facilitate pilot adaptation to be guided by switchable centre line lights.

3.4.3.14 *Visual aid instructions* — Green lights in front mean “follow”. Where the pilot is instructed to follow the green lights, the absence of such lights indicates that the pilot or vehicle driver should stop. Red lights mean “stop”, and yellow or flashing lights mean “caution”.

Automatic light control by surveillance information

3.4.3.15 It should be feasible to design a guidance system to be controlled automatically, if only in part, by the surveillance function in conjunction with the routing function. In this respect, taxiway lighting could be automatically switched on or off along the required route. This is a system development that might be explored in the future, as well as the automation of other visual aids.

Visual docking guidance system (VDGS)

3.4.3.16 Conventional visual markings for stand entrance and parking are being replaced by more complex VDGSs. These systems are able to give precise information on alignment and distance to go to flight crew members. Some are able to detect the type of aircraft. Such VDGSs should be integrated within the A-SMGCS.

3.4.4 Control

General

3.4.4.1 The design of any control system should take into account the requirements for safety and efficiency. It should also take into account the taxi performance and limitations of all relevant aircraft and vehicles.

3.4.4.2 The control function should be able to handle:

a) deviations from assigned routes;

b) operational changes (e.g. runway changes, routes closed for maintenance, and temporary hazards or obstacles);

c) priority routes designated to drivers of emergency and operational vehicles; and

d) different groups of participants which can affect safety, including aircraft, authorized airport vehicles, other airport vehicles (without any communication) and intruder vehicles.

Longitudinal spacing

3.4.4.3 Substantial research work will be required to establish longitudinal separation requirements for ground movement. In order to calculate the required longitudinal spacing, the following parameters should be considered:

a) the distance covered by the "following" aircraft during the *total time* required for the pilot, controller and A-SMGCS to react;

b) the distance needed for an aircraft to stop;

c) the minimum distance to be maintained between two aircraft at all times excluding jet blast effects; and

d) the sum of the aircraft length and the distance behind the aircraft that must be kept clear to avoid jet blast effects.

Longitudinal spacing = a) + b) + c) + d) = St

Note.— The parameters are illustrated in Figure 3-2.

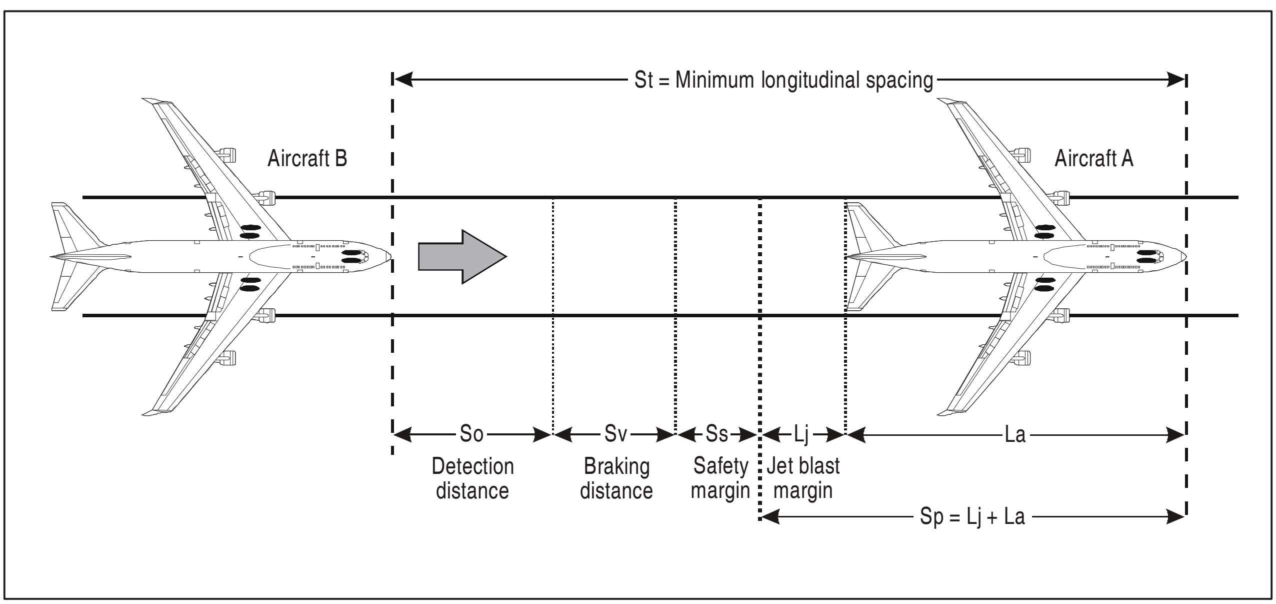


Figure 3-2. Longitudinal spacing parameters

3.4.4.4 Other parameters that should be specified to enable longitudinal spacing to be calculated are:

a) Va — the initial speed of aircraft A (km/h);

b) Vb — the initial speed of aircraft B (km/h);

c) Aa — the deceleration of aircraft A (m/s^2);

d) Ab — the deceleration of aircraft B (m/s^2);

e) Pir — pilot reaction time (s);

f) Cor — controller reaction time (s);

g) Syr — system reaction time (s); and

h) Sar — safety reaction time (s).

Total time = e) + f) + g) + h) = Ts

Reliability

3.4.4.5 The following parameters should be considered in the specification of control reliability requirements:

a) *probability of detection of an alert (PDA) situation* — the number of correct alert reports generated by the A-SMGCS over a given period of time, expressed as a percentage of the total number of alert situations arising over the same period of time; and

b) *probability of false alert (PFA)* — the number of false alert reports generated by the A-SMGCS over a given period of time, expressed as a percentage of the total number of alert reports recorded over the same period of time.

3.4.5 Conflict alert

3.4.5.1 The objective of the control, guidance and routing functions should be to prevent a collision between aircraft, vehicles and other objects on the manoeuvring area. This objective could extend to the prevention of a conflict.

3.4.5.2 The control function should be able to handle:

a) deviations from assigned routes;

b) events that impose operational changes (e.g. runway changes, routes closed for maintenance, and temporary hazards or obstacles);

c) priority routes designated to drivers of emergency and operational vehicles; and

d) different groups of participants which can affect safety, including aircraft, authorized airport vehicles, other airport vehicles (without any communication) and intruder vehicles.

3.4.5.3 The surveillance function contributes to situational awareness and enables a continuous monitoring and assessment of conformance with the intended movements.

3.4.5.4 Once detected or predicted, a conflict should be resolved according to its severity. There should be sufficient time to resolve a predicted conflict through the planning process. However, an actual conflict requires immediate action, which may be a system- or human-initiated resolution.

3.4.5.5 During visibility conditions when the "see and be seen" principle can be applied without reducing aerodrome capacity, the longitudinal spacing facility of an A-SMGCS may only be required to detect possible conflicts.

3.4.5.6 An important aspect in conflict alert is the differentiation between detected and predicted conflicts (see Figure 3-3). A detected conflict, which requires immediate action to prevent a collision, should be given priority over a predicted conflict, which requires expeditious action to avoid the development of an imminent situation. The alerting system should indicate this difference by providing a different set of alerts to the users of the system.

3.4.5.7 Every aerodrome has site-specific parameters and situations to be addressed. The following list provides some of the possible conflict alert scenarios that should be both predictable and detectable by the A-SMGCS:

a) runway conflicts:

1) aircraft arriving to, or departing aircraft on, a closed runway;

2) arriving or departing aircraft with traffic on the runway (including aircraft beyond the runway-holding positions);

3) arriving or departing aircraft with moving traffic to or on a converging or intersecting runway;

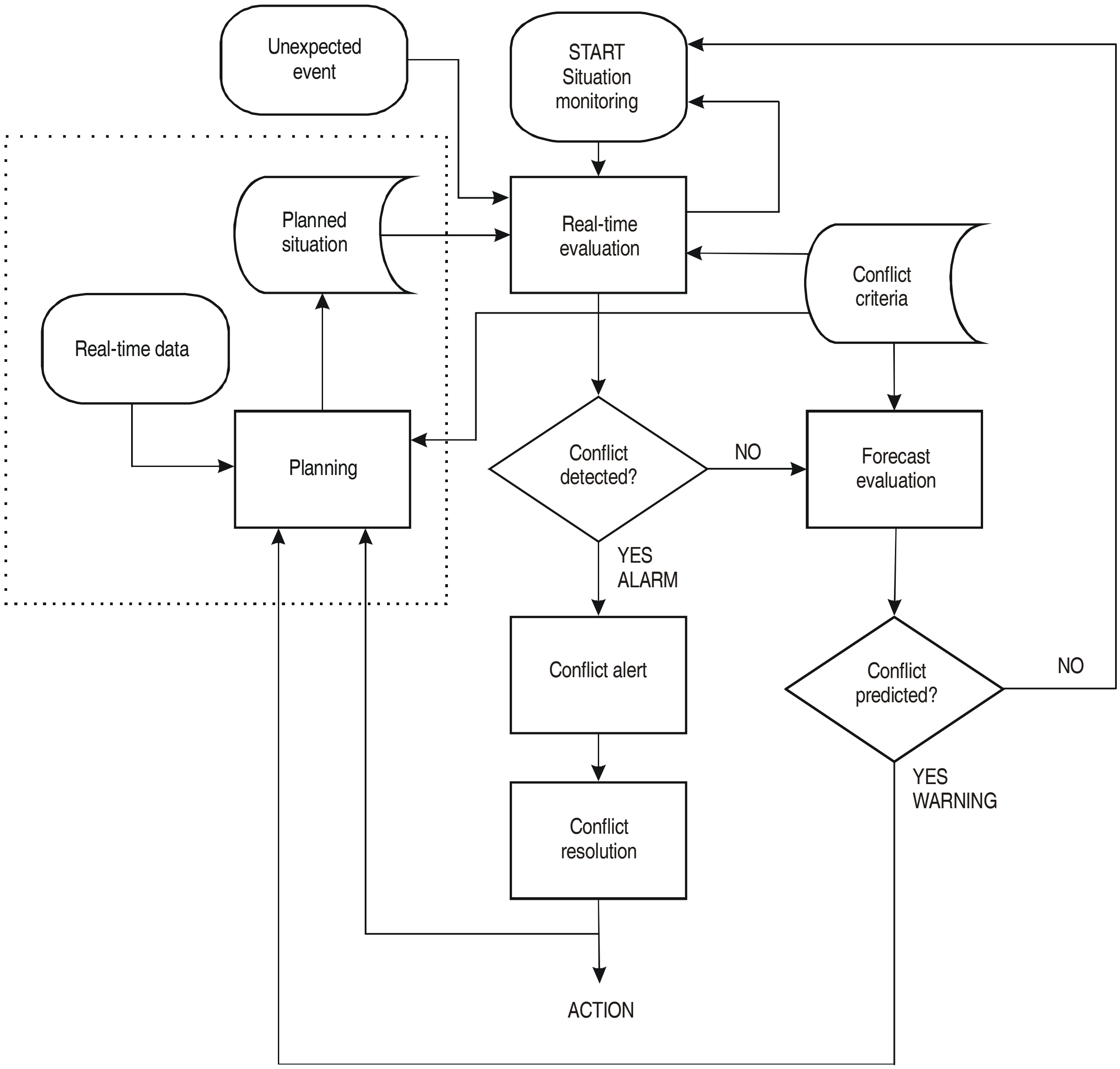


Figure 3-3. Conflict alert

4) arriving or departing aircraft with opposite direction arrival to the runway;

5) arriving or departing aircraft with traffic crossing the runway;

6) arriving or departing aircraft with taxiing traffic approaching the runway (predicted to cross the runway-holding position);

7) arriving aircraft exiting runway at high speed with converging taxiway traffic;

8) arriving aircraft with traffic in the sensitive area (when protected);

9) aircraft exiting the runway at unintended or non-approved locations;

10) unauthorized traffic approaching the runway; and

11) unidentified traffic approaching the runway;

b) taxiway conflicts:

1) aircraft on a closed taxiway;

2) aircraft approaching stationary traffic;

3) aircraft overtaking same direction traffic;

4) aircraft with opposite direction traffic;

5) aircraft approaching taxiway intersections with converging traffic;

6) aircraft taxiing with excessive speed;

7) aircraft exiting the taxiway at unintended or non-approved locations;

8) unauthorized traffic on the taxiways;

9) unidentified traffic on the taxiways; and

10) crossing of a lit stop bar; and

c) apron/stand/gate conflicts:

1) aircraft movement with conflicting traffic;

2) aircraft movement with conflicting stationary objects;

3) aircraft exiting the apron/stand/gate area at unintended or non-approved locations; and

4) unidentified traffic in the apron/stand/gate area.

Vehicle movements should also be considered in all the alert scenarios above.

3.4.5.8 An alert associated with a detected conflict should be provided within an adequate time and brought to the attention of the controller and pilot and/or vehicle driver involved. An alert associated with a predicted conflict (a warning) should also be provided.

3.4.5.9 The design of the conflict alert system should deploy algorithms that follow a set of specific rules. These rules should consider the effect of:

a) the type of traffic;

b) the speed and direction of the traffic (linear and non-linear track prediction);

c) the speed and braking performance;

d) the proximity to certain areas of the movement area where the risk of a conflict is high (e.g. runway-holding positions and runway intersections); and

e) dynamic scenarios (e.g. when a taxi route deviation occurs).

3.4.5.10 Advanced ground surveillance systems that contain conflict alerting logic must constantly analyse large amounts of data for aircraft and vehicle track position and prediction. System limitations may dictate that only a finite number of aircraft can be processed at an acceptable update rate, or that all aircraft can be processed at a reduced update rate. While it is agreed that a robust system should process all aircraft and vehicles at an acceptable rate, priorities should be established so as to ensure that system logic performs efficiently. The runway represents the area with the highest risk of a catastrophic event. Therefore, the detection and prediction of conflicts in this area should be addressed first. Conflict alerting priorities should be as follows:

1. runway conflicts;

2. taxiway conflicts; and

3. apron/stand/gate conflicts.

3.4.5.11 The area monitored should be the runway strip or the protection area needed for the precision approach and landing aid in use, whichever is the most restrictive.

3.4.5.12 When an aircraft is within 30 seconds from touchdown, the monitored area should be checked for the presence of targets. If a target is found that meets the alert criteria, the attention of the controller should be raised.

3.4.5.13 When the aircraft is within 15 seconds from touchdown, an alarm to the controller should be initiated if the presence of a target is detected within the monitored area. The controller should be able to acknowledge the alarm and take the necessary action.

3.4.5.14 Conflict information should be unambiguously displayed on a surveillance display or by other appropriate means. The information should be displayed continuously while the conflict is present. In visibility condition 4, the conflict information should be presented to the pilots concerned as well as the controller. In addition, it is desirable that this information be made available to pilots in other visibility conditions.

3.4.5.15 The criteria used to determine whether an alert should be raised depends on a comparison of the speed and course of the arriving aircraft with that of the target on the ground and the calculation of the time at which they will be closest. It is important to reduce the number of false or nuisance alerts, especially in good visibility conditions. When a departure is closely followed by an arrival on the same runway, no alert should be raised if the departure is moving at a relatively high speed and the distance between the two is increasing.

3.4.5.16 For departures where two or more targets are detected within the monitored area at the same time, an alert should be raised to remind controllers that more than one aircraft or vehicle occupies the runway. The alert should remain until only one target is on the runway, or when one target reaches a predefined speed and it can be assumed that it is taking off. In this case, the area in front of the departure should be monitored and any target found should generate an alert.

3.4.5.17 Taxiways and aprons should be monitored and an alert raised to the controller and pilot and/or vehicle driver for the following potential conflicts:

a) loss of wing-tip spacing due to manoeuvring;

b) head-on conflicts;

c) incursions (unauthorized entry onto a taxiway or apron, or failure to comply with an instruction to hold or give way); and

d) route conflicts (i.e. where two or more given routes provide a collision risk).

3.5 SUPPLEMENTARY REQUIREMENTS

3.5.1 Global risk factor

3.5.1.1 With the employment of new procedures and increased movement rates in all types of conditions, the use of an A-SMGCS should maintain and, where possible, increase the safety of aerodrome operations.

3.5.1.2 It is stated in Doc 9476 that the risk of a fatal accident should not exceed one in 10^7 operations. The same figure for overall level of safety should be used in reviewing the performance of an A-SMGCS.

3.5.1.3 This figure represents the safety objective or target level of safety (TLS) for the entire flight operation, including take-off, climb, cruise, approach, landing and taxi. It is applied to the combination of the various systems, procedures and tools in use at an aerodrome, including aircraft operational aspects. The TLS for aerodrome surface operations, including the contribution of an A-SMGCS, has been determined from an analysis of accident data from European and United States sources. The analyses are summarized in Appendix D.

3.5.1.4 Different areas on the aerodrome may require or allow different safety requirements. Therefore, A-SMGCS at different aerodromes may have unique sets of safety requirements. However, the level of safety afforded by using an A-SMGCS in combination with other systems and procedures at an aerodrome or within the ATM system will need to meet the overall TLS.

3.5.1.5 The level of safety at the aerodrome should be continuously measured and monitored. Any occurrence that results in an actual or perceived reduction in safety below the target level should be investigated, and if necessary, remedial action should be taken to improve safety and prevent a reoccurrence.

3.5.2 Aircraft types

A-SMGCS should be usable by all aircraft types that are equipped to operate under all weather operations procedures. In principle, this involves all commercial air transport operations, and a high proportion of general aviation and military transport aircraft.

3.5.3 Vehicles

3.5.3.1 The number of vehicles permitted on the manoeuvring area should be kept to a minimum. In very low visibility conditions, it should be limited to those essential for the support of operations.

3.5.3.2 The following principles should normally apply:

a) access to all parts of the manoeuvring area should be strictly controlled and limited to:

   1) emergency vehicles; and

   2) ATS or aerodrome operational (e.g. runway inspection) vehicles;

b) additional vehicles which may require access to runways or taxiways include:

   1) runway maintenance vehicles or sweepers;

   2) snow clearance vehicles; and

   3) aircraft tugs;

c) to the extent practicable, vehicles authorized to operate on the manoeuvring area should be equipped to meet the appropriate A-SMGCS requirements and should be subject to similar control procedures as aircraft; and

d) on aprons, in addition to the vehicles specified above, a large number of vehicles require access to service aircraft and would normally be strictly segregated. A limited number of service vehicles and/or tugs require access to areas of the apron which are also used by aircraft and would need to be equipped for A-SMGCS in low visibility conditions. A larger number of service vehicles can primarily be contained within designated areas of each apron, immediately adjacent to, but not obstructing, the parking of aircraft that they serve.

In low visibility conditions, the movement of vehicles as indicated above needs strict control by the control authority.

3.5.4 Speeds and orientation

3.5.4.1 In good visibility, aircraft exit runways at speeds of up to approximately 90 km/h (50 kt) and taxi at speeds of up to approximately 55 km/h (30 kt) on straight sections of taxiways; they reduce speed to about 20 km/h (10 kt) on curves and on complex taxiway configurations. Helicopters may air taxi at higher speeds.

3.5.4.2 In low visibility conditions, lower speeds may be more prudent; however, if runway capacities are to be maintained and taxiways are not to become congested with aircraft, it will be important to maintain speeds similar to those normally used in good visibility. Constant stopping and starting should be avoided. The ability to follow a preceding aircraft at a fixed distance at a fixed speed will be important. It will be even more important for the A-SMGCS to incorporate known taxiing times so that aircraft can arrive at the runway-holding position in the correct time to meet their approved departure time.

3.5.4.3 The A-SMGCS might require information on movements that are not on the surface and/or are outside the aerodrome boundary. Therefore, an altitude requirement should be specified. In addition, altitude information would provide important data for the determination of wake turbulence, rotor wash and other similar hazards.

3.5.4.4 The A-SMGCS should, where appropriate, include helicopter operations that may not adhere to the same arrival, departure and taxi routes used by fixed-wing aircraft.

3.5.5 Susceptibility

The designer of the A-SMGCS should consider factors such as:

a) electrical immunity from other systems at the aerodrome; and

b) the specific requirements and limitations existing at the aerodrome. These may include:

   1) the area to be covered by the A-SMGCS, and the number and location of runways, taxiways, aprons, etc.;

2) the position and view from the control tower or any other location from where part or all of the aerodrome control service will be provided;

3) the location of buildings and other obstructions;

4) the location of external or remote components of the A-SMGCS, including their availability and maintainability; and

5) the effect of meteorological conditions on the performance of the A-SMGCS.

3.5.6 Reference system

3.5.6.1 The adoption of WGS-84 may require significant efforts in order to cover every aerodrome and its facilities. The use of advanced navigational techniques or guidance will necessitate that a universal and correct standard be employed, in particular, where the autonomous ability of aircraft avionics is used.

3.5.6.2 The following points on the aerodrome should be provided:

a) the aerodrome reference point (ARP);

b) a topography representation; and

c) a topology representation.

3.5.6.3 The ARP, given in WGS-84 coordinates, should be used by the A-SMGCS as the origin of an *x-y* grid, with the *x*-axis oriented east/west and the *y*-axis north/south. For A-SMGCS internal calculation, any other point of the aerodrome will be referenced to the ARP in metres using the *x-y-z* grid.

3.5.6.4 In order to correlate the aerodrome relevant points to the ARP, all the calculations will derive from the WGS-84 coordinates of the different points obtained in accordance with the *World Geodetic System — 1984 (WGS-84) Manual* (Doc 9674).

3.5.6.5 The topography representation will be the numerical representation of topopoints and toposhapes within the aerodrome and its surrounding area.

3.5.6.6 A map with information on topopoints, given by the coordinates and height of points, should be provided for, *inter alia,* the following geographical points:

a) thresholds;

b) runway limits;

c) holding positions;

d) stop bars;

e) runway exits;

f) taxiway intersections;

g) intersection limits;

h) switchable centre line light block limits;

i) parking positions; and

j) building corners.

Each point should have a unique identifier.

3.5.6.7 The toposhape structure should describe the three-dimensional shape of an object. It should have a unique identification and a list of associated topopoints.

Topopoints survey requirements

3.5.6.8 Figure 3-4 shows the topography points for thresholds. For surveying purposes, the threshold topopoint should be taken as the centre of the runway at the beginning of the runway portion usable for landing. Where the edge of the runway is irregular or connected to a taxiway, an appropriate theoretical line, which best identifies the probable edge of the runway, should be selected. When the threshold is displaced, the topopoint should be the centre of the threshold mark.

3.5.6.9 The distance from the point surveyed as the threshold to the end of the paved surface at the near end of the runway should be determined to an accuracy of 10 cm.

3.5.6.10 Where the threshold is displaced, the runway limit topopoint should be given as the centre of the runway at the end of the paved surface.

3.5.6.11 The holding position topopoint should be surveyed at the intersection of the holding position marking and the taxiway centre line (see Figure 3-5). Where different holding positions are in use according to visibility conditions, all should be surveyed.

3.5.6.12 The stop bar topopoint should be surveyed at the intersection of the stop bar and the taxiway centre line.

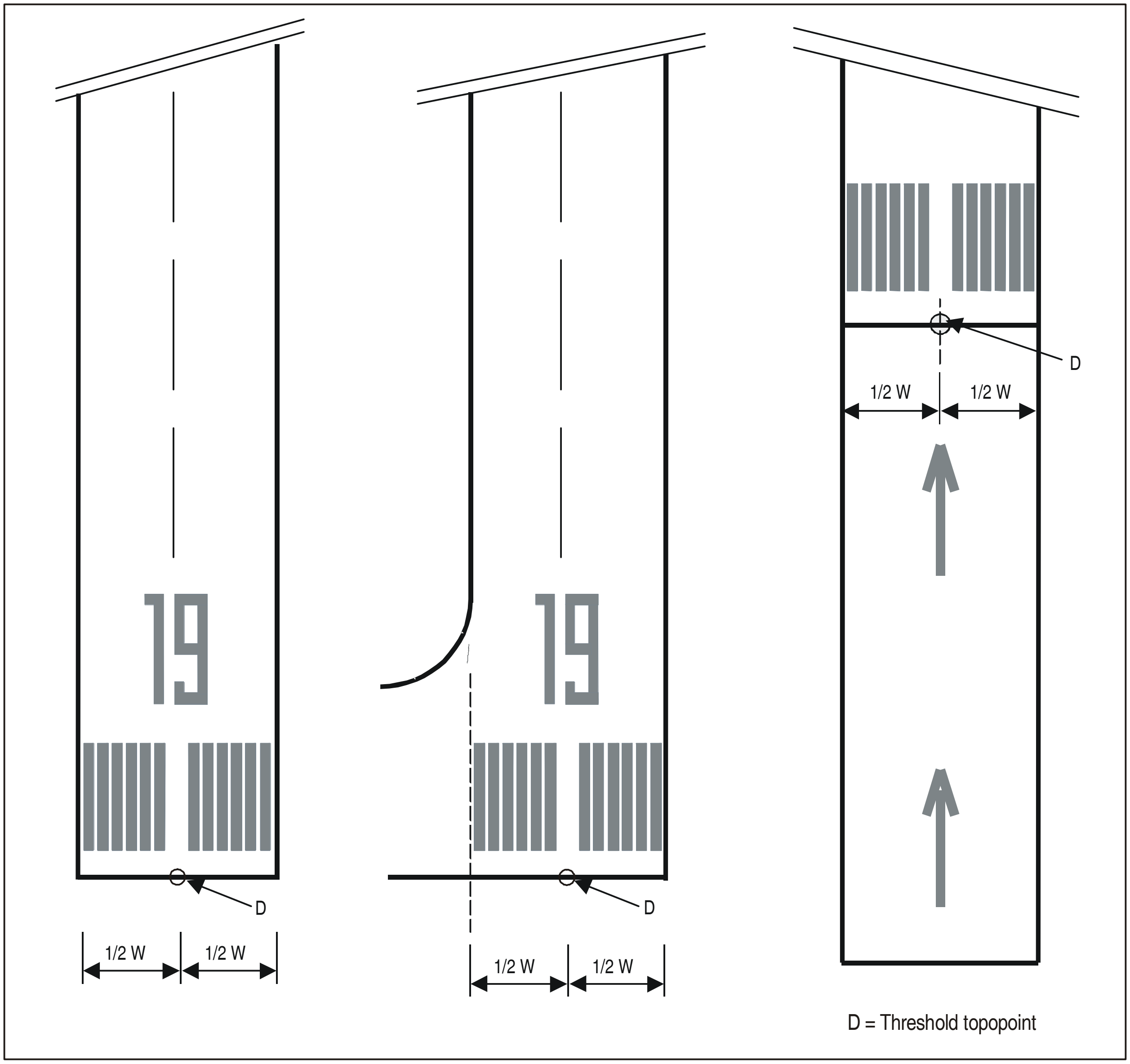
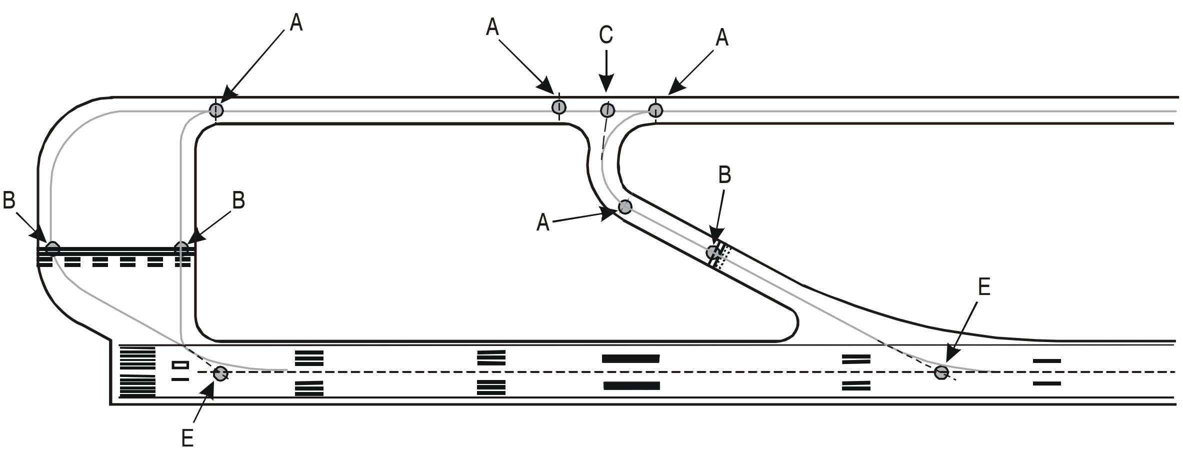


Figure 3-4. Topography points — thresholds



Runway holding points (B), runway exits (E), taxiway intersections (C) and intersection limits (A)

Figure 3-5. Topography points — holding positions, runway exits and taxiway intersections

3.5.6.13 The runway exit topopoint should be surveyed at the intersection of the runway centre line and the extension of the nearest straight section of the taxiway centre line (see Figure 3-5).

3.5.6.14 Taxiway intersections should be given by the intersection of taxiway centre lines or of the extension of the nearest straight section of the taxiway centre line (see Figures 3-5 and 3-6).

3.5.6.15 The intersection limits should be given by the intersection of the taxiway centre line and the intersection indication. Where centre line lights are installed, this point should be the same as the beginning of the intersection switchable centre line light blocks (see Figures 3-5 and 3-6).

3.5.6.16 The centre line light block topopoints should be surveyed on the centre line at the centre of two consecutive centre line lights, each of which belongs to a different block (see Figure 3-7).

3.5.6.17 The following points related to parking positions should be surveyed:

a) the point where the taxiway centre line intersects the limit of the stand; and

b) the point on the axis of the stand where the front wheel or the pilot position is expected to be when the aircraft is stopped. If several points are available, the farthest one from the point indicated in a) should be surveyed.

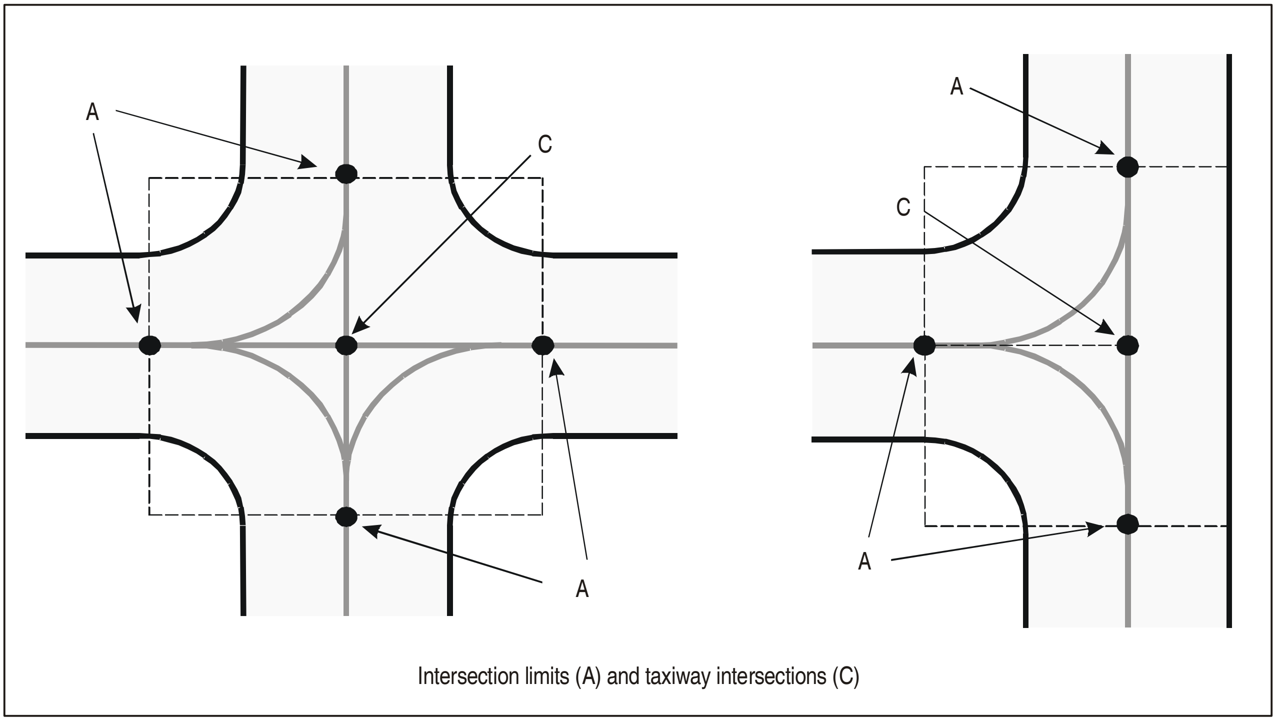


Figure 3-6. Topography points — taxiway intersections

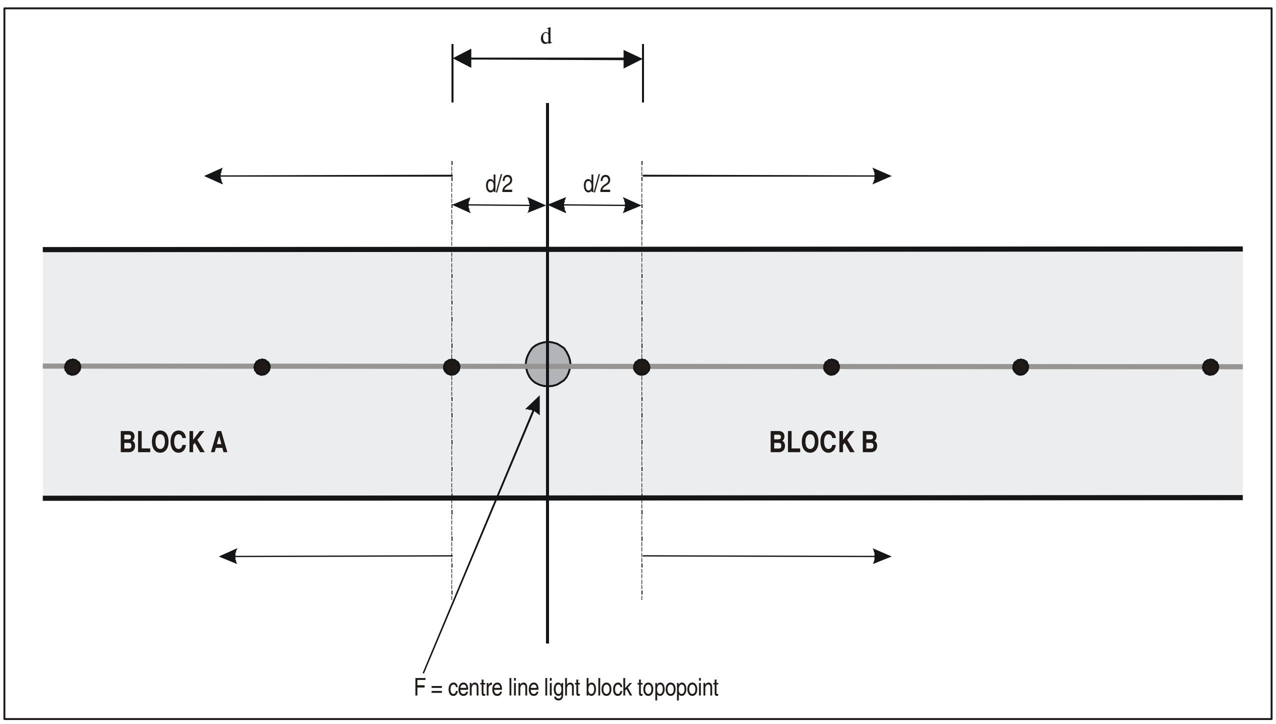


Figure 3-7. Topography points — taxiway blocks

3.5.6.18 For A-SMGCS purposes, Table 3-1 lists the accuracy of the WGS-84 coordinates for the different aerodrome points.

3.5.6.19 The topology representation should be the logical representation of the aerodrome layout as used by pilots and controllers (see Figure 3-8).

3.5.6.20 A network of lines, each of which should be given between two topopoints, should represent runways, taxiways and apron taxiways. These lines should be called "links" or "transitions" (TL), and their ends, "nodes" or "junctions" (TN).

3.5.6.21 Runways, taxiways and aprons should be divided into blocks, or sections and intersections (B) according to the switchable centre line light blocks capability. They should be identified by the same identification as used by the aerodrome for the centre line light blocks.

3.5.7 Reference point

3.5.7.1 A common reference point on aircraft and vehicles should be established for use in A-SMGCS. Any of the following points may be considered:

a) the mid-point of the longitudinal axis of the aircraft or vehicle; or

b) the pilot or vehicle driver eye reference position; or

c) the nose wheel of an aircraft or a front wheel of a vehicle; or

d) the nose of the aircraft.

3.5.7.2 For the purpose of providing accurate position, vector and identification information, it is desirable that a single reference point be established for all systems.

3.5.8 Planning

3.5.8.1 It is critical to the efficient and flexible operation of any aerodrome that planning elements can be tactically adjusted to meet changing circumstances.

3.5.8.2 Aerodrome operations are vulnerable to many factors which must be taken into account in planning operations. These factors include weather conditions that may require an adjustment of movement rates or landing and take-off directions. Additionally, unserviceable equipment and movement surfaces may require the use of non-routine procedures and routing. Closures of sections of the movement area for maintenance or snow clearance may exceed the allocated expected time.

3.5.8.3 Planning activities will include prediction of aerodrome capacities, gate allocation and ground movement plans for departures and arrivals. The ground movement planning will calculate different possible routes for each aircraft and vehicle taking into account the predicted capacities, gate/slot allocation, minimum taxi times and delays. These plans will be modified — steadily reducing time horizons down to pre-tactical planning (typically 20 minutes in advance). From that moment, the automated routing function, or the aerodrome controller in the event of an automated routing function not being available, will be tasked to assign an appropriate route for each aircraft and vehicle. The route will be chosen from those proposed by the tactical plan, if available, or from predetermined routes, or if none of these selections suit the actual needs of the ground movement situation, the route will then be calculated by the system. The route assigned will depend solely on the ground movement situation that exists at the time when the route is issued.

3.5.9 Recordings

To enable an accurate reconstruction of the aerodrome operations, including operator inputs, all data should be recorded at several locations within the A-SMGCS, including on board aircraft. It is desirable that any recorded data can be accessed and replayed without the need for specialized software/hardware tools and knowledge.

3.5.10 System failures

3.5.10.1 The A-SMGCS should have sufficient redundancy, fault tolerance or failure mitigation to enable operations to continue or be downgraded without affecting the required level of safety. This applies to both hardware and software failures that cause an interruption or loss of an A-SMGCS function. A back-up procedure should be provided for any known potential failure.

3.5.10.2 The possibility of an unpredictable and catastrophic failure should be considered. In the event of such a failure, procedures should be provided whereby dependence on the system (which may be the entire A-SMGCS) can be removed.

Table 3-1. Accuracy requirements for reference points

Aerodrome point	*Accuracy*
Thresholds	1 m
Runway limits	1 m
Holding positions	0.5 m
Stop bars	0.5 m
Runway exits	0.5 m
Taxiway intersections	0.5 m
Intersection limits	0.5 m
Switchable centre line light block limits	2.5 m
Parking positions	0.5 m

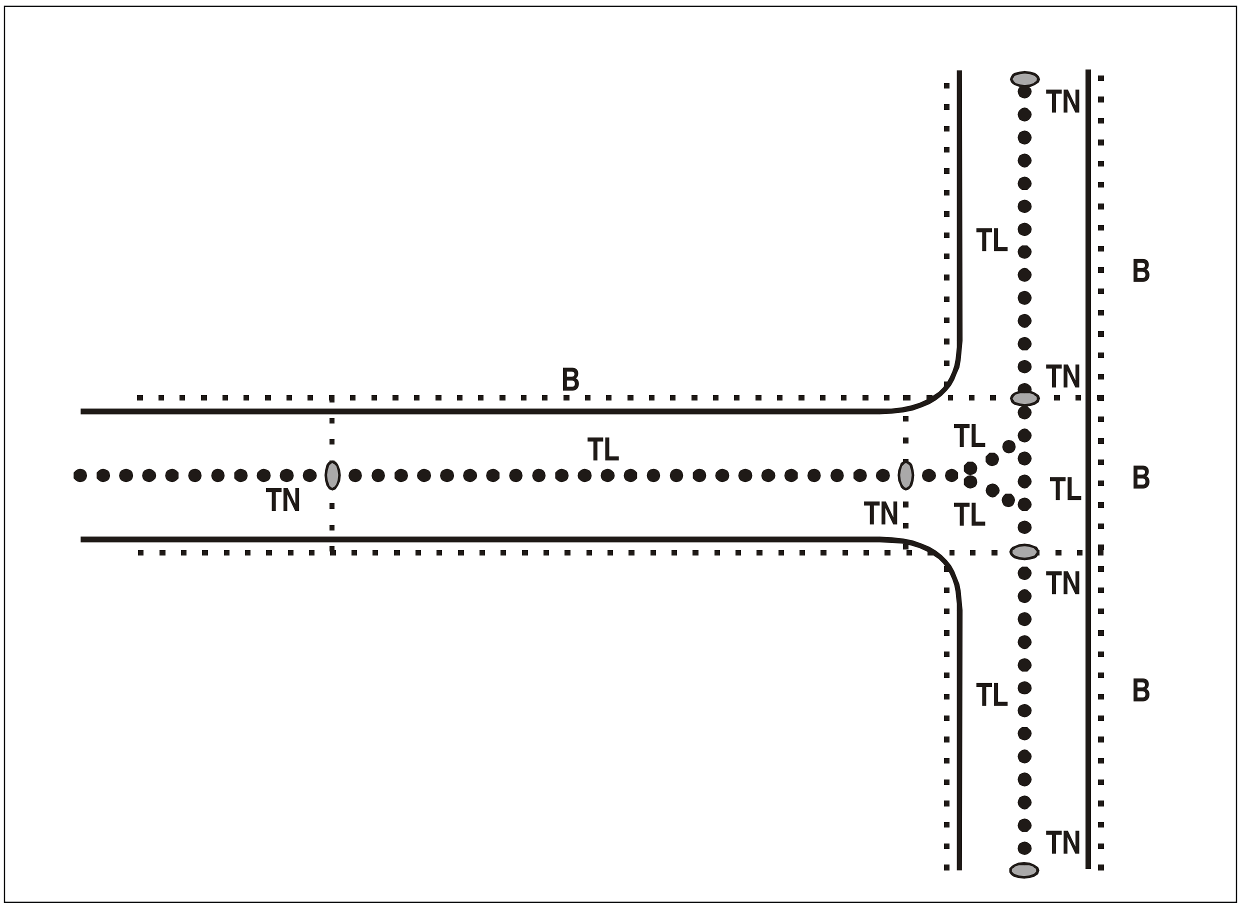


Figure 3-8. Topology points

3.5.11 Start up and restart

When switching on any part of the A-SMGCS, the equipment should perform an internal system check, including a check of the accuracy of any data, and then be capable of providing operational service with minimum intervention by the user.

3.5.12 Aerodrome considerations

3.5.12.1 The siting considerations for A-SMGCS equipment at an aerodrome should not differ from those of existing SMGCS. Many requirements for SMGCS are contained in Annex 14, Volume I.

3.5.12.2 An A-SMGCS should be designed so that, wherever possible, changes to the aerodrome will not require a major reconfiguration of the A-SMGCS or its components. A means of system expansion that upgrades the service and allows the augmentation of extra facilities should be incorporated.

3.5.12.3 The effect of an A-SMGCS on aerodrome operations should be considered in the following areas:

a) the utilization of the movement area in all proposed operational conditions;

b) instrument landing system (ILS) critical and sensitive area protection (if applicable);

c) ATC procedures (especially in low visibility conditions);

d) fire and rescue vehicle operations (especially in low visibility conditions);

e) other ground vehicle operations;

f) existing lighting, markings and signage; and

g) existing structures and their illumination.

3.5.13 ATC considerations

Automation in ATC

3.5.13.1 Few aerodromes have an ideal layout; most have been extended and adapted over time and, therefore, have a varied and complex structure. Few have been constructed with automatic operations taken into account in their design. This is further complicated by the introduction of new larger aircraft, which will result in restrictions as to which taxiways certain aircraft can use, introducing a greater need for flexibility.

3.5.13.2 With the introduction of an A-SMGCS at an aerodrome, ATC will be responsible for the management and overall operation of the system; however, certain functions will be delegated to automated elements of the system.

3.5.13.3 A different division of functions among the control personnel may be necessary and may vary as a result of a possible change in procedures caused by automation. The allocation of functions and/or responsibilities might differ depending on the visibility condition, level of automation and level of implementation of an A-SMGCS. Part or all of the decision-making process of some functions may have to be allocated to the system itself.

3.5.13.4 Automation should be introduced in a modular form, and each element should be independent (capable of operating when other elements have become unserviceable). Interfaces should be provided to enable controllers to take over the operation of failed elements. These interfaces should also make it possible for staff to adjust the functioning of automated elements during normal operation when inappropriate system function or unplanned events require amendments to the operation. For example, there may be occasions when equipment failure or weather conditions require that an automated planning element be adjusted to reduce the start-up rate of departures.

3.5.13.5 HMI and automation concepts will require a careful balance in design. While it is recognized that a proliferation of displays and input devices must be avoided, there must also be sufficient duplication to provide back-up services. The search for the correct balance of equipment integrated into the controller workstation will be one of the major tasks in the system design.

3.5.13.6 Training aids should be provided to ensure that staff are able to operate the equipment, and that they are fully trained in situations where automated functions need to be taken over after a failure. This training should not end in the initial phases of introduction, but be continuous to maintain staff competency.

ATC functional requirements

3.5.13.7 For surveillance, the controller should be provided with a situation display of the area of responsibility of the ATC unit, showing the position and identification of aircraft and vehicles under the control of that unit. Unauthorized targets which enter the area of responsibility, especially the active runway strips, should also be displayed.

3.5.13.8 When required, the system must allow for manual input by ATC to select alternative routes to support a particular operational need. The methods of manually indicating routing instructions should be simple to operate so as not to detract from other primary tasks.

3.5.13.9 ATC must be able to monitor routing instructions that are automatically allocated and be able to intervene with re-routing instructions.

3.5.13.10 Where applicable, all control authorities concerned should be provided with methods of guiding aircraft and vehicles on the movement area from their current positions to their intended destinations, including guidance to any intermediate positions that may be required. Voice communication will remain a primary method of providing guidance.

3.5.13.11 An A-SMGCS should provide additional control capacity and redundancy to enable ATC to continuously control situations which may have progressed beyond the standard operations initially anticipated.

ATC and human-machine interface (HMI)

3.5.13.12 Actual traffic flows are not merely a progression from stand to runway and vice versa. There will be a great need for flexibility as aircraft may be unable to depart in the established sequence, e.g. when changing weather conditions fall below the operating minima of some operators. Technical failures may require aircraft to return to the stand at any time right up to and including the take-off roll. The effective integration of the human element into the system design can help to provide this flexibility.

3.5.13.13 If human operators are to provide any meaningful contribution to the operation of an A-SMGCS, even if only in a monitoring role and providing backup in the event of system failure, they should be involved in the executive functions of the system. Humans are poor monitors. When performing monitoring tasks, humans may be unable to take over the functions of a system if they have not been involved in its operation.

3.5.13.14 Human error is a major cause of failure in current systems. Automation should be deployed in such a way as to create an environment that will enable staff to maximize their flexibility and have the ability to deal with unexpected situations, while minimizing the opportunities for error.

3.5.14 Pilot considerations

3.5.14.1 The safety of aircraft must be protected at all times. Therefore, the pilot of each aircraft should be provided with adequate information to safely taxi the aircraft in all operational conditions, with the knowledge that the system will prevent collisions with other aircraft or vehicles.

3.5.14.2 Specific positive measures should be provided to prevent runway incursion by aircraft or vehicles under any visibility conditions.

3.5.14.3 The system should provide the capacity for aircraft and essential vehicles on the movement area commensurate with the runway capacity. It should also enable predetermined taxiing speeds to be maintained to ensure timely arrival on stands and at the runway-holding position.

3.5.14.4 In order to achieve the above, the pilot should in all operational conditions be provided with:

a) information on the aircraft's location and direction at all times;

b) continuous guidance and control during:

   1) the landing roll-out;

   2) taxiing to the parking position and from the parking position to the runway-holding position;

   3) lining up for an appointed take-off position; and

   4) the take-off roll;

c) indication of the route to be followed, including changes in direction and indication of stops;

d) guidance in parking, docking and holding areas;

e) indication of spacing from preceding aircraft, including speed adjustments;

f) indication of spacing from other aircraft, vehicles and obstacles in visibility condition 4;

g) indication of the required sequencing;

h) information to prevent effects of jet blast or propeller/rotor wash;

i) identification of areas to be avoided;

j) information to prevent collision with other aircraft, vehicles or known obstacles;

k) information on system failures affecting safety;

l) the location of active runways;

m) alert of incursion onto runways and taxiways; and

n) the extent of critical and sensitive areas.

Note.— Most of the foregoing requirements may be satisfied by using ground visual aids.

3.5.14.5 Any technological solution to achieving situational awareness should be fully compatible with developments in avionics and other technologies, e.g. enhanced vision systems that are being considered for other modes of all weather operations.

3.5.14.6 The operational procedures of A-SMGCS should be standardized, with no significant variations, at all aerodromes where all weather operations are conducted.

3.5.14.7 Upon touching down on the runway, pilots require precise guidance to assist them in their deceleration, to identify and locate the designated rapid exit taxiway, and then to follow an unambiguous route on the taxiway to the assigned stand. When leaving the stand, they again require guidance to follow an unambiguous route to the designated holding position for the assigned runway, as well as guidance to line up on the centre line of the runway.

3.5.14.8 The guidance at holding positions and on the apron should be adequate for aircraft to be manoeuvred in the same close proximity as in unrestricted visibility. The guidance on taxiways should be adequate for the aircraft to follow the taxiway centre line. It should incorporate positive measures to prevent erroneous routing and specifically to prevent unauthorized entry (incursion) onto an active runway. Current systems of high-intensity green centre line lighting are generally adequate for all but the lowest visibility. Systems that can be switched to indicate the designated route and that use stop bars to control conflicting traffic from converging routes are advantageous. The use of additional stop bars at intervals along a designated route to prevent an aircraft from catching up to another aircraft is likely to restrict capacity, and the resulting stop/start procedures are uneconomical.

3.5.14.9 Supplementary or alternative technical solutions to provide more precise guidance may be operationally acceptable if they can be economically justified and not result in significantly different visual presentations to pilots from one aerodrome to another.

3.5.14.10 The system may need to be augmented by equipment in the aircraft or vehicle for operations in visibility condition 4.

3.5.14.11 Pilots require unambiguous and direct conflict-free routings between the runway and the stands. The selection of these routes will be a control authority responsibility. To achieve adequate capacity, it may be necessary to implement unidirectional routes to and from the runway. If data link is used, it should satisfy the pilots' requirements for the receipt and display of routing, situational awareness and conflict detection and resolution.

3.5.14.12 The detection and resolution of conflicts will mainly be a system function. The pilots of the aircraft concerned and/or the drivers of the vehicles concerned should be advised of all relevant conflicts. The following situations may require action:

a) active runway ahead;

b) crossing or stationary aircraft/vehicle ahead or close to one side;

c) preceding or diverging, slower-moving aircraft/vehicle;

d) converging aircraft/vehicle; and

e) head-on conflict.

3.5.14.13 At an aerodrome with a high traffic density, there are likely to be a number of conflicts arising simultaneously. These will be beyond the capability of a single controller to resolve. The system will need to detect and display the situation and the resolution either to the control authority or to the pilot in such terms as:

a) stop or reduce speed;

b) wait until detected visually;

c) re-route via ...;

d) wait until situation resolved; and

e) go around.

3.5.14.14 To maintain capacity, the control authority may deliberately route aircraft or vehicles in close proximity to each other. In low visibility conditions, visual detection alone may not be adequate. In these cases, the system should provide adequate spacing between the aircraft/vehicles involved. The pilot requirements for this are:

a) to be advised of the relative location of proximate aircraft, vehicles or obstructions;

b) to be instructed by the control authority on the action to take; and

c) to be provided with adequate guidance to maintain the required spacing from aircraft or vehicles in close proximity.

3.5.14.15 In very low visibility conditions, these actions may require additional equipment on the aircraft to enable manoeuvres such as:

a) to follow a preceding aircraft along a taxiway at a predetermined distance; and

b) to pass by another aircraft or vehicle at close range.

3.5.15 Vehicle driver considerations

3.5.15.1 A vehicle driver operating on the movement area, with the exception of passive and empty stands and controlled taxiway road crossings, should be provided with radiotelephony capability and adequate information to enable the driver to operate the vehicle in all operational conditions, with the knowledge that the system will prevent a collision with aircraft and vehicles.

3.5.15.2 Specific positive measures should be provided to prevent incursion by vehicles onto an active runway under any visibility conditions.

3.5.15.3 Specific positive measures should be provided to prevent incursion by unauthorized vehicles onto the movement area.

3.5.15.4 The system should provide guidance and control for rescue and fire fighting vehicles in order for them to reach any point on the movement area within the required response time. The system should also provide for operational vehicles that carry out essential duties on the movement area, e.g. surface inspections, bird control, de-icing and snow clearance.

3.5.15.5 Authorized vehicles permitted only on apron roads (including controlled and uncontrolled crossings), and passive and empty stands should not be subject to control by an A-SMGCS.

3.5.15.6 Facilities should be provided for the drivers of all vehicles to be aware of their proximity to the movement area. Additionally, facilities should be provided for the driver of each controlled vehicle to be aware of:

a) the location and direction of the vehicle on the movement area;

b) the assigned route to follow, in particular, when that route includes taxiways and/or runways;

c) the relative proximity of any possible conflict on the movement area;

d) the location of any active runway;

e) the extent of runway clear and graded area and strip; and

f) the extent of navigation aid critical and sensitive areas.

3.5.15.7 In most circumstances, situational awareness could be provided by the use of standard lighting, markings and signage.

3.5.15.8 All vehicle drivers who are required to drive on the movement area should receive formal training and certification that they are qualified to drive the types of vehicles or equipment which they will operate. Such training should include all rules and procedures applicable to the aerodrome and knowledge of those aspects of an A-SMGCS which apply to vehicle drivers, including the use of radiotelephony, when applicable.

3.5.15.9 All vehicle drivers who are required to drive on the movement area need to be tested to ensure that they meet the necessary medical requirements, including hearing and colour vision.

3.5.16 Apron management/airport authority considerations

3.5.16.1 At aerodromes operating an A-SMGCS, all vehicles required to move on the movement area should be equipped to use the system. However, to be so equipped is unnecessary and uneconomical for those vehicles that service aircraft on the stand only because they only move onto the stand once the aircraft has parked.

3.5.16.2 An "active stand" is included in the movement area while a "passive stand" is not. A vacant stand is defined as an "empty stand" and is excluded from the movement area. Therefore, the status of stands is as follows:

a) active stand — a stand that is occupied by a stationary aircraft with engines operating, or on which an aircraft is moving, or which is being approached by an aircraft. When an aircraft is being pushed back or is under tow, the stand is also active. When a stand is active, all vehicles must remain clear of that stand or within designated areas on the stand;

b) passive stand — a stand that is occupied by a stationary aircraft with engines not operating. At this time, vehicles not under individual control may leave designated roadways and parking areas and move in the proximity of the aircraft to perform servicing tasks; and

c) empty stand — a vacant stand not being approached by an aircraft. This stand is available for allocation to incoming aircraft; until then, the movement of vehicles on the stand is not restricted.

3.5.16.3 It is not practicable to exercise total control over all traffic on the movement area. On the apron, an A-SMGCS applies only to those areas where manoeuvring aircraft may come into conflict with each other or with vehicles. Therefore, one requirement is to restrict the movement of vehicles on the apron to designated areas and routes. It is also necessary to keep service vehicles away from an active stand. This can be achieved by having painted lines that outline the areas to be left clear when a stand is active. Alternate means of protecting an active stand might become available as a result of technology. It is important that any new solutions retain flexibility to enable an A-SMGCS to operate fully during aircraft movements and, in addition, permit service vehicles access to the stand once the aircraft has parked.

3.5.16.4 Authority to change the status of each stand to match its activity will normally be vested in the appropriate control authority. It may be necessary to introduce distinctive coloured light signals at each stand to indicate its status.

3.5.16.5 At aerodromes where the movements of aircraft and vehicles are authorized in conditions of very low visibility conditions (<75 m RVR), conventionally painted demarcation lines in the vicinity of stands may require additional fixed (selectable) lighting to ensure segregation between aircraft and vehicles.

3.5.16.6 When adequate visibility permits the "see and be seen" principle to be applied, it may not be necessary to strictly enforce the declaration and updating of the status of each stand. However, at least at aerodromes where the procedure is implemented in low visibility conditions, it may be considered good operating practice to continue to apply the procedure in all visibility conditions.

3.5.16.7 The A-SMGCS functions established for the apron should be compatible with those for all other areas to ensure the safe and orderly transition of aircraft and vehicles from the apron to other areas.

3.5.17 Automation

3.5.17.1 The use of automation is one of the main differences between SMGCS and A-SMGCS. SMGCS will evolve to include elements of the functions of A-SMGCS, such as control, guidance and route assignment. The evolution to an automated system will mean a safer and more efficient operational environment but at the same time, it may mean a more complex environment for human interaction.

3.5.17.2 Any automation should undergo a thorough validation process to ensure that the operational requirements are met. The validation process needs to encompass all environmental and failure conditions, including the reversion to manual control.

3.5.18 Human-machine interface (HMI)

3.5.18.1 Although they do not specifically address A-SMGCS, the contents of the ICAO Human Factors Digests are applicable to the various stages of development, introduction, management, training, etc. of advanced technologies.

3.5.18.2 At least for the foreseeable future, there is a requirement for pilots to continue to operate their aircraft with no external steering or control facilities during normal taxi operations. The guidance and control elements of A-SMGCS should, therefore, be optimized for use by the pilots. Additionally, if the flexibility of human operators within A-SMGCS is to be maximized, then Human Factors issues are equally important.

3.5.18.3 The basic limitation and a primary design factor is the ability of pilots, vehicle drivers and system operators to interpret the guidance and control elements of A-SMGCS and to carry out their respective responsibilities.

3.5.18.4 The flight deck tasks are composed of a sequence of visual, audio and tactile operations. Care should be taken in the balance of these actions to ensure that there is not an overload in any one area. The need for the crew to retain control of the aircraft has already been stated. The difficulty of navigating in low visibility conditions will place a high workload in the visual area, with a high degree of concentration required. Care should be taken that no one factor is used to the limit.

3.5.18.5 The factors mentioned in 3.5.18.4 apply equally to the tasks of the staff operating the system. Although direct observation is restricted during times of low visibility, it does not remove the need for this task. It is envisaged that A-SMGCS will not only be in operation during times of low visibility conditions, but also in all weather conditions to maximize the capacity of the aerodrome. At the very least, there will be situations during transition to and from low visibility conditions when visual observations will be possible and will be a necessary part of the operation.

3.5.18.6 ATC should always have the capability to observe the aerodrome activity. Speech and audio input enable the operator to carry out other tasks, including observation, while keyboard and message displays require a higher level of visual concentration and tactile actions. Advanced technology will require the use of such interfaces, but their use should be balanced so as not to detract from other essential tasks.

3.5.18.7 It is recommended that users and operators of systems be involved in the design of relevant system elements at an early stage so that operational functions can be optimized for their use. This will be critical to the efficiency and effectiveness of the system.

3.5.19 Interfaces

3.5.19.1 The aerodrome operation is an integral part of the overall ATM system. Aerodrome capacity should be matched to the ability of the surrounding airspace system to handle the generated air traffic. There should be a seamless exchange of information between the A-SMGCS and ATM systems.

3.5.19.2 There are three prime users of A-SMGCS: controllers, pilots and vehicle drivers. Each of them needs to be able to interface with the system. Additionally, the system will need to interface with other systems.

3.5.19.3 System interface with pilots and vehicle drivers should, in principle, be based on visual aids and radiotelephony with the possibility in the future of augmentation with on-board displays and air-ground data links.

3.5.19.4 Information required by the A-SMGCS from other systems includes, but is not restricted to, the following:

a) runway allocation;

b) arrival/departure sequence;

c) aircraft type;

d) aircraft identification;

e) estimated time of arrival (ETA) and estimated time of departure (ETD);

f) stand allocation (if done by a different system);

g) meteorological data;

h) emergency situations;

i) priorities;

j) slot allocation; and

k) infrastructure limits (e.g. maintenance purposes and aircraft de-icing).

3.5.19.5 Information required to be transmitted by an A-SMGCS to other systems includes, but is not restricted to, the following:

a) actual time of arrival/departure;

b) data to enable actual aerodrome capacity to be monitored;

c) aerodrome equipment, services and procedures available;

d) aeronautical ground light status;

e) surface movement emergency situations;

f) real time of stand allocation;

g) estimated early stand arrival; and

h) aborted take-off situations.

3.5.19.6 The need to automatically register all communication data affecting operations should be studied.

3.6 SYSTEM REQUIREMENTS

3.6.1 Accuracy

3.6.1.1 The term "accuracy" generally describes the degree of conformance between a true position and speed, and its estimated position and speed.

3.6.1.2 The accuracy requirement of an A-SMGCS will depend on several factors including:

a) the category of the aerodrome;

b) the functional complexity of the A-SMGCS design; and

c) the level of dependency on automation.

3.6.1.3 The true value of the accuracy requirement of an A-SMGCS should be determined by a safety assessment carried out for the specific aerodrome.

3.6.2 Integrity

3.6.2.1 "Integrity" relates to the trust which can be placed in the correctness of the information provided by an A-SMGCS. Integrity includes the ability of an A-SMGCS to provide timely and valid alerts to the users when the A-SMGCS should not be used.

3.6.2.2 In the event of any failure, an appropriate alert including the operational significance of the failure should be provided.

3.6.2.3 A safety assessment should be carried out on the level of integrity and should be directly related to the TLS. Other integrity requirements include:

a) determination of the integrity risk — the probability of an undetected failure, event or occurrence within a given time interval should be ascertained;

b) error identification — an error detection process should be deployed that will maintain the required level of integrity;

c) error classification — each detected error should be analysed and a corrective or error-processing method should be initiated within a specified time;

d) error handling — the number of attempts or retries allowed within a given time period to complete an error-free function, transaction or process before a failure is declared should be specified;

e) data integrity and validation — latent data within an A-SMGCS should be continuously checked for its integrity. This includes data that have a specified life cycle and that are contained within databases; and

f) information errors — the propagation of hazardous or misleading information should be prevented.

3.6.2.4 Access to an A-SMGCS and the ability to perform certain functions (such as system configuration) should be restricted to authorized personnel only. The service providers should ensure that an A-SMGCS's integrity level addresses the hazards posed by unlawful, accidental or other unauthorized access. Procedures should be in place for the detection of access violations and the consequences of such actions.

3.6.3 Availability

3.6.3.1 In case of a system failure that has a long-term effect on the availability of the A-SMGCS, appropriate action (e.g. promulgation of NOTAM) should be taken to notify all users of the system status.

3.6.3.2 An A-SMGCS is an integral part of the overall aerodrome operations and a significant part of the ATM system. The required level of availability should therefore be equal to or better than that of other integral systems within the aerodrome or the ATM system.

3.6.3.3 During essential maintenance, the availability of all the functions within an A-SMGCS should not be affected at the same time. Fault tolerance and maintainability should be maximized so that an A-SMGCS with reduced capability would still be able to offer a safe and efficient level of service.

3.6.3.4 When an A-SMGCS is designed with one or more of its functionalities dependent on on-board equipment, the system should have the ability to safely handle aircraft with unserviceable equipment.

3.6.3.5 The operational needs of an individual aerodrome include:

a) weather conditions under which take-off and landing can be performed;

b) necessity for improved surveillance, routing, guidance or control capabilities that are not achievable with conventional SMGCS;

c) any safety aspects under any weather condition;

d) consideration of interrelation between functions; and

e) consideration of interrelation between functions on destination and alternate.

3.6.4 Continuity

3.6.4.1 "Continuity" is the ability of an A-SMGCS to perform its required function without non-scheduled interruption during the intended operation.

3.6.4.2 In accordance with the system performance and safety requirements, an A-SMGCS should be designed such that the probability of an interruption during the performance of a critical function or service will not exceed the acceptable limit.

3.6.5 Reliability

3.6.5.1 There is a very close link between the required integrity of an A-SMGCS and the reliability of the system. In order to get a highly reliable system with high integrity, it is sometimes necessary to duplicate or even triple components, thereby increasing the cost and complexity. Also, at some point there is usually a failure transfer mechanism which, being a common mode failure point, could be detrimental to the reliability. Often a compromise is reached depending on the criticality of the component and its functionality.

3.6.5.2 Important reliability aspects to consider are:

a) the criticality of a system component with regard to the functionality;

b) how a failure is detected;

c) that all critical failures will be detected;

d) how a failure impacts upon the system functionality;

e) how a failure is contained or handled; and

f) how the user is notified of the failure.

Chapter 4

PERFORMANCE REQUIREMENTS

4.1 SYSTEM REQUIREMENTS

4.1.1 General

4.1.1.1 Prior to the implementation of an A-SMGCS, the system performance and functional requirements should be demonstrated in order to ensure that the design specifications or requirements have been met.

Safety

4.1.1.2 The A-SMGCS target level of safety (TLS) should be 1×10^{-8} collisions per operation involving aircraft on the ground.

4.1.1.3 The function risk has been estimated as:

a) guidance: 3×10^{-9} per operation;

b) surveillance: 3×10^{-9} per operation;

c) control: 3×10^{-9} per operation; and

d) routing: 1×10^{-9} per operation.

Coverage

4.1.1.4 The A-SMGCS should cover at least the movement area of the aerodrome as well as aircraft on approach to each runway at such a distance that inbound aircraft can be integrated into the A-SMGCS operations.

Capacity

4.1.1.5 The A-SMGCS should be able to handle all aircraft and vehicles that are on the movement area at any time.

4.1.1.6 The determination of the maximum number of aircraft on the manoeuvring area should be based on the assumed peak traffic at the aerodrome. The A-SMGCS capacity should be sufficient to cater for increased capacity, and it should be reviewed on a regular basis to ensure that it is sufficient.

Speeds

4.1.1.7 The A-SMGCS should accommodate all aircraft and vehicle speeds that will be used within the coverage area with sufficient accuracy.

4.1.1.8 The A-SMGCS should be able to accommodate the following speeds determined to within ± 2 km/h (1 kt):

a) 0 to 93 km/h (50 kt) for aircraft on straight taxiways;

b) 0 to 36 km/h (20 kt) for aircraft on taxiway curves;

c) 0 to 150 km/h (80 kt) for aircraft on runway exits;

d) 0 to 460 km/h (250 kt) for aircraft on final approach, missed approach and runways;

e) 0 to 150 km/h (80 kt) for vehicles on the movement area; and

f) 0 to 20 km/h (10 kt) for aircraft and vehicles on stands and stand taxilanes.

4.1.1.9 For all aircraft and vehicles moving at speeds within the ranges described above, the A-SMGCS should be able to perform the surveillance and guidance functions in accordance with, and without degradation of, the control and routing functions. This is particularly relevant to the switching of visual aids and human-related functions.

4.1.1.10 The A-SMGCS should determine the direction of movement in terms of the magnetic heading of each participating aircraft and vehicle to within ± 1°.

4.2 SURVEILLANCE REQUIREMENTS

Note.— It is expected that more than one type of surveillance sensor will be needed to meet the surveillance requirements.

4.2.1 The surveillance function should be capable of detecting aircraft, vehicles and obstacles. Methods should be employed to reduce adverse effects such as signal reflections and shadowing to a minimum.

4.2.2 A reference point on aircraft and vehicles is required to enable the A-SMGCS to determine their positions. Although this requirement applies to the surveillance function, it is used predominantly in the control and guidance functions.

4.2.3 The actual position of an aircraft, vehicle or obstacle on the surface should be determined within a radius of 7.5 m. Where airborne traffic participates in the A-SMGCS, the level of an aircraft when airborne should be determined to within ±10 m.

4.2.4 The position and identification data of aircraft and vehicles should be updated at least once per second.

4.2.5 The latency and validation of surveillance position data for aircraft and vehicles should not exceed 1 second. The latency and validation of identification data for aircraft and vehicles should not exceed 3 seconds.

4.3 ROUTING REQUIREMENTS

4.3.1 The requirements listed in Table 4-1 should be used in the design of the routing function.

4.3.2 The time taken to process an initial route should not exceed 10 seconds. Reprocessing to account for tactical changes once the aircraft or vehicle is in motion should not exceed 1 second.

4.3.3 In the processing of optimized routes, the length of taxi distances should be computed to a resolution better than 10 m, and timing to a resolution better than 1 second.

4.4 GUIDANCE REQUIREMENTS

4.4.1 The overall response time of initiation of the guidance to verification that the correct route or information has been provided should not exceed 2 seconds.

4.4.2 The reversion time should be a maximum of 0.5 second.

4.5 CONTROL REQUIREMENTS

4.5.1 The probability of detection of an alert (PDA) situation should be greater than 99.9 per cent. The probability of false alert (PFA) should be less than 10^3.

4.5.2 The response time of any control function should be less than 0.5 second.

4.5.3 Longitudinal spacing (see Figure 3-2) should be based on the following typical numerical values:

a) Va = 55 km/h (30 kt);

b) Vb = 55 km/h (30 kt);

Table 4-1. Routing maximum failure rate requirements

Visibility condition	*Requirement (Failures per hour)*
1	1.5E-03
2	1.5E-04
3	3.0E-06
4	1.5E-06

c) Aa = 1 to 2 m/s^2 (depending on aircraft weight, friction coefficient, etc.);

d) Ab = 1 to 2 m/s^2 (depending on aircraft weight, friction coefficient, etc.);

e) Pir = 1 s;

f) Cor = 1 s;

g) Syr = 2 s; and

h) Sar = 1 s.

4.5.4 On the basis of calculations using the above data, it can be concluded that:

a) a design taxi speed of 55 km/h (30 kt) is practicable;

b) a longitudinal spacing (St) of approximately 200 m, with aircraft taxiing in trail, will be required to achieve the minima specified below; and

c) a minimum spacing when the aircraft have stopped (Ss + Lj) of approximately 60 to 15 m can be provided by the system, with the lower figure applying to holding positions.

Chapter 5

IMPLEMENTATION ISSUES

5.1 INTRODUCTION

The following paragraphs outline some of the steps that might be taken prior to and during the design and implementation of an A-SMGCS, particularly with respect to the assurance that the A-SMGCS will meet the requirements of the aerodrome and provide a solution to the safety and/or capacity problems at the aerodrome.

5.2 CAPACITY ASSESSMENT

5.2.1 General

5.2.1.1 It should be ensured that the system will always have sufficient capacity to accommodate the aerodrome traffic demand while maintaining a predetermined capacity margin, i.e. to ensure a correct capacity/demand balance (CDB).

5.2.1.2 The CDB should also be used to alert those concerned when demand drops below capacity so that measures can be taken to save resources.

5.2.2 Capacity management

The following different capacities should be taken into account:

a) theoretical capacity — capacity that is calculated for existing facilities (layouts, systems, etc.) and comprises:

   1) apron capacity — maximum number of aircraft (with indication of types) that can be parked;

   2) taxiway capacity — maximum number of aircraft that can be operated on the taxiways at the same time;

   3) runway capacity — maximum number of runway movements per hour; and

   4) approach capacity — maximum number of transfers between the aerodrome controller and approach controller.

Each of the above-mentioned capacities should be calculated using both design and operational values, and they should be referred to in predetermined units of time.

b) downgraded capacity — aerodrome capacity that is derived from the theoretical capacity which has been reduced due to facility limitations (failures, maintenance, weather conditions, local regulations, etc.). The different values should be calculated taking into account the following:

   1) long term — activities related to stored flight plan arrivals and departures;

   2) short term — activities related to en-route, inbound or pre-departure aircraft; and

   3) real time — activities related to actual aircraft movements on and in the vicinity of the aerodrome.

5.2.3 Demand management

5.2.3.1 As for capacity, the demand should be allocated to the different aerodrome areas (apron, taxiway and runway), taking into consideration arriving, departing and parked aircraft.

5.2.3.2 To obtain the different demand values throughout the complete time horizon, the system should take into account not only the flight plans and aircrew or airline requests, but also temporary constraints as well as unusual traffic peaks and unexpected arrivals due to restrictions at other aerodromes.

5.2.4 Mechanisms for balancing demand and capacity

5.2.4.1 Problems will arise whenever the ratio between capacity and demand gets closer to one.

5.2.4.2 The value of the predetermined margin, which will reflect the uncertainties in assessments of demand and capacity, must be given to the system in the implementation phase. It should be modified later to reflect experience gained.

5.2.4.3 The time available for anticipating problems is a key factor in determining which actions should be taken. The further in advance predictions can be made, the wider the range of options which can be applied.

5.2.4.4 Depending on the time horizons, i.e. from months in advance to the actual situation, different actions can be taken to either modify the demand or the capacity. The following present some of the possible actions:

a) for the long term:

   1) increase capacity of the critical (bottleneck) resource; and/or

   2) reduce demand for that resource by modification of stored flight plans (only after confirmation that there is no other solution);

b) for the short term:

   1) modify flight plans of en-route, inbound or departing aircraft; and/or

   2) divert arriving aircraft to other aerodromes (only after confirmation that there is no other solution); and

c) for real time:

   1) reallocate slots for departing aircraft.

5.3 COST/BENEFIT ASSESSMENT

5.3.1 General

5.3.1.1 The use of cost/benefit analyses helps decision makers to determine the best alternative to system development and deployment of equipment and services supporting A-SMGCS. While the complexity of aerodrome surface movement increases as visibility decreases, the benefits may accrue in increments not directly related to visibility. For example, if the sharing of information on take-off delays can produce efficiencies in air traffic management, this benefit could be realized in any visibility condition. Those aerodromes developing A-SMGCS capabilities should consider visibility conditions in their cost/benefit analyses, but not as the only factor.

5.3.1.2 Risk analyses can measure the improvements expected through changes in procedures or addition of technology. Risk analyses produce a probability of an event (i.e. runway incursion, surface collision, etc.). An improvement proposed for an aerodrome should show a reduction in risk.

5.3.1.3 Benefits expressed in terms of cost avoidance, aircraft loss, loss of life, disruption to aerodrome services, cost of investigation, etc. can be used to turn risk reduction into a quantitative value. However, because surface accidents are rare, these cost avoidance savings may be “soft” savings, meaning that they may or may not be realized.

5.3.1.4 Quantifiable benefits tied to efficiency can be determined, and improvements assessed against these benefits. Savings expected can be measured after the procedural change or addition of technology. The aerodrome users can validate expected savings in terms of reduced delay, taxi-in and taxi-out time, aircraft turn-around time at the gate, improved aircraft servicing, improved aerodrome capacity (in terms of throughput expressed as operations per hour), or reduced operating costs. Efficiency benefits accrue with every operation, while safety benefits may remain unseen. Regarding safety benefits, there are no guarantees that an accident will not occur, even though risk is reduced.

5.3.1.5 The conduct of cost/benefit analyses will vary with standard economic practices of States and aerodromes. The assessment should provide the basis for modifying the approach to fit the needs. Those doing cost/benefit analyses can vary from the assessment methodology proposed provided the ground rules, assumptions and data are made available. This will allow aerodrome users and others to apply their own methodology to determine the benefit for their operations.

5.3.2 Cost/benefit guidelines

The primary benefits for operators are related to improved operating efficiencies. Aerodrome and air traffic control benefits include both safety and efficiency. Safety and efficiency benefits should be segregated in the analyses to facilitate decision making. Guidelines for conducting a cost/benefit analysis are listed below:

- Define and provide measures of changes in capacity to the maximum extent possible. This will allow the aerodrome user to determine whether the capacity gain warrants improved aircraft equipage.

- Consider benefits which may occur due to avoidance of costs associated with diversions and cancellations, including the cost of getting passengers to their final destination.

- Identify hourly costs of taxi time, which may be different from hourly block time costs traditionally used in cost/benefit analyses. The taxi time cost is more representative of surface operations cost.

- Consider benefits which may occur due to improved command and control, not just air traffic management improvements. The sharing of surveillance information can provide command and control benefits for the aerodrome operator and service providers on the aerodrome.

- Use aerodrome traffic growth forecasts or national growth forecasts to estimate future demand.

- Use historical weather data for projected operating hours in visibility conditions 1 through 4.

- Wherever possible, incremental analyses should be undertaken so that only the additional benefits of a new initiative, net of any previous initiatives, can be determined. Modular addition of capabilities to improve services is the basis of any A-SMGCS implementation. Cost/benefit analyses should be modular also to capture incremental improvements.

- Use current and projected costs and determine overall cost using life-cycle costing. A life-cycle cost estimate includes the cost of research, engineering and development, acquisition, operation, decommissioning and disposal. In the event that an alternative solution or project requires user equipage, these costs must be included. Both non-recurring and recurring costs should be considered. The source of the cost data should be explained for each major cost element.

- The method of computing cost and benefit values should be explained, including discounting, proportional distribution of benefits, yearly distribution of costs and benefits, and timing for realizing benefits or incurring costs.

- A module in an A-SMGCS may have value for operations beyond surface movement. Therefore, analyses should define how benefit and cost segments are attributed to surface applications.

- Previously procured systems have already been justified based on their own merits. The cost of sustaining an existing system such as an operational surface movement radar should not be charged against an A-SMGCS unless a new radar with improved performance would be required. In this case, a replacement system should be considered as one of the modules for cost/benefit analyses.

- Non-personnel-related cost avoidance should be considered, which may include maintenance savings, reduced telecommunications costs, leases, rents, utilities, and the deferral or elimination of the need to make a capital investment.

- Secondary user benefits should be identified. An A-SMGCS produces information as a product. Whether it be improved surface surveillance, scheduling information, gate allocations, etc., this information has value to service providers beyond air traffic control, the aerodrome users and the aerodrome operator.

- System performance trade-offs should be considered in balancing cost and benefit. There may be opportunities to meet the goals of an A-SMGCS through trade-offs in technology and procedures. A good cost/benefit analysis will consider each alternative and the modules defined within the envisioned system. These trade-offs should be clearly defined so that others reviewing the analysis and the decision makers can consider them.

5.3.3 Identifying benefits

5.3.3.1 Benefits are improvements realized over the existing baseline capability. Starting with the operational requirements given in this manual, add local, site-specific user and aerodrome requirements. Compare the existing baseline operating capabilities to those proposed in the new operational requirements for an A-SMGCS. Define who gets the benefits. This allocation of benefits will help in quantifying both the benefits and the costs. The allocation will also help in developing the assumptions that will be used in the analyses.

5.3.3.2 Table 5-1 provides a representative breakdown of benefits. This table should be modified, as necessary, for each particular aerodrome.

Table 5-1. Benefits breakdown

Service provider benefits		
ATM service providers	• Controller productivity • Maintenance productivity • Leased communications savings • Rent, utility, other savings • Liability cost savings • Future capital cost avoidance	
Other air navigation service providers	• Productivity • Maintenance productivity • Leased communications savings • Rent, utility, other savings • Liability cost savings • Future capital cost avoidance • Reduced service cost to user	
Aerodrome service providers	• Increased capacity (operations per hour) • Operations productivity • Maintenance productivity • Improved passenger handling • Improved rescue response • Reduced time when runway(s) unusable	
User benefits		
Delay savings	Air carrier	• Aircraft operating cost savings • Diversion avoidance • Reduced flight cancellations
	Commuter and air taxi	• Aircraft operating cost savings • Diversion avoidance • Reduced flight cancellations
	General aviation	• Aircraft operating cost savings
	Military aviation	• Aircraft operating cost savings • Improved all weather capability

User benefits		
Safety	• Fatalities avoided • Injuries avoided • Aircraft losses avoided • Aircraft damage avoided • Ground vehicle damages avoided	
Efficiency	Air carrier	• Aircraft operating cost savings • Aircraft turn-around time reduced • Personnel savings • Maintenance savings • Avoided capital investment cost
	Commuter and air taxi	• Aircraft operating cost savings • Aircraft turn-around time reduced • Personnel savings • Training savings • Maintenance savings • Avoided capital investment cost
	General aviation	• Aircraft operating cost savings • Aircraft turn-around time reduced
	Military	• Aircraft operating cost savings • Aircraft turn-around time reduced • Personnel savings • Maintenance savings • Avoided capital investment cost
Information user efficiencies	• Improvements in command and control • Improved level of service • Personnel savings • Training savings • Maintenance savings • Aircraft turn-around time reduced • Passenger/cargo throughput improvements	

5.3.3.3 Table 5-2 provides a listing of potential users of information provided by A-SMGCS. The table was developed to identify primary and secondary users of information. Some aerodrome authorities may restrict the access to information provided by an A-SMGCS.

5.3.4 Identifying cost

5.3.4.1 Cost should be defined as life-cycle cost. In the past, air traffic control systems were developed with an expected life cycle of 20 years. This trend is changing with the introduction of improved, cost-effective automation and reliance on commercial products. An air traffic control hardware life of 5 to 10 years is becoming more common. Commercial airlines expect a 20-year life cycle for equipment installed by the aircraft manufacturer. For equipment installed by the airline, the life cycle is in the order of 5 to 7 years for avionics, while the cost recovery for avionics is typically 3 to 5 years.

Table 5-2. Information users

User	*Terminal surveillance*	*Surface surveillance*	*Flight plan data*	*Arrival data list*
Air traffic control	x	x	x	
Apron management	x	x	x	
Operations (airline)	x	x	x	x
Operations (aerodrome)	x	x	x	x
Maintenance aerodrome		x	x	x
Snow removal team	x	x	x	x
Rescue and fire fighting		x		
Noise monitoring	x			
Finance (landing fees)				x
Flight information display systems			x	x
Ground transportation			x	x
Baggage handling			x	x
Fuelling			x	x
Catering			x	x
Customs and immigration			x	x
Lodging facilities			x	x

Note 1.— Terminal surveillance allows position and time to be reported for aircraft in the terminal area.

Note 2.— Surface surveillance reports position of aircraft and vehicles in the manoeuvring areas. If surveillance coverage is extended to the ramp area, then surface surveillance will have increased value for control.

Note 3.— Flight plan data provides departure information with gate/stand identified.

Note 4.— Arrival data list contains the expected landing time and gate/stand arrival time, with gate identified.

5.3.4.2 Table 5-3 contains the user cost breakdown. The project cost breakdown of ground equipment is provided in Table 5-4. These cost tables show examples of potential sources of cost. Each A-SMGCS may produce different cost sources. The primary objective is to develop a list of applicable cost sources early in the analyses. As in the benefit analyses, it is important to solicit participation from all affected service providers and users early in the process.

5.3.4.3 Another metric for economic justification is net present value — the discounted value of expected net benefits (i.e. benefits minus costs). In order to compute net present value, benefit and cost streams are discounted by a specified rate. This discount rate may vary with each State. The rate also differs within the user community.

5.3.5 Recommended outline for a cost/benefit analysis and report

It is recommended that an outline for a cost/benefit analysis and report contain:

- A brief summary of objectives, costs, alternatives investigated, methodology, and benefits and costs assessed;
- Discussion of any historical data that helps to define the shortfall in capabilities and application of any previous cost/benefit studies which will be used;
- A description of the current baseline, shortfalls in the existing system, and proposed solutions to overcoming these shortfalls;

Table 5-3. User cost breakdown

Users	*Sources of costs*
Acquisition	• Hardware • Firmware • Software • Installation • Opportunity (out-of-service) costs • Engineering • Integration • Testing and certification • Training development • Management • Cost of funding
Operations	• Labour • Training • Leased communications • Facilities • Utilities
Maintenance	• Out-of-service cost • Labour • Training • Spares • Logistics • Test equipment • Maintenance management
Information users	• Leased communications • Hardware • Software • Training • System maintenance • Utilities

Table 5-4. Project cost breakdown of ground equipment

Service providers	*Sources of costs*
Project management	• Management efforts • Financial management • Planning and scheduling • Contract management • Data management
Systems engineering	• Engineering management • Interface management • Configuration management • Quality assurance • Production management • Transition management • Technical monitoring • Operational requirements • System design
Pre-production	• Proof of concept • Prototype development • Deployment costs
Prime mission equipment	• Hardware • Firmware • Software • Integration • Production/assembly
Testing	• Test programme • Developmental testing and evaluation • Operational test and evaluation
Data	• Technical manuals • Engineering data • Data depository • Other documentation
Training	• Training requirements analysis • Training manuals • Management • Course development • Course delivery
Integrated logistics	• Logistics management • Support equipment • Spares • Warehousing • Facility requirements
Site activation	• Site procurement • Site survey • Environmental assessments • Site preparation • Site installation and checkout

Service providers	*Sources of costs*
Operational support	• Contractor maintenance • Direct work maintenance • Supply support • Support equipment • Training and training support • Leased communications • Facilities • Utilities • Periodic inspection and/or certification
Disposal	• Disposal management • Dismantle/decommission • Demolition • Environmental audits • Hazardous waste management • Facility construction or conversion • Site restoration • Salvage value recovery

- Technical and procedural alternatives that can fulfil the mission needs, the characteristics of each alternative, and whether each alternative meets all or a portion of the mission needs;

- A description of each ground rule and assumption used in identifying costs and benefits, including factors used to discount values;

- A description of methods used to estimate benefits and costs, equations used, and data sources referenced;

- An assessment of life-cycle costs consistent with the ground rules and assumptions used. Parametric, vendor quotes, and analogy methods should be used to estimate life-cycle costs and extrapolate costs over the life cycle;

- A description of benefits identified, presented in a modular fashion so that incremental benefits can be understood;

- A comparison of benefits and costs for each alternative with a ranking in terms of the most benefit for the least cost; and

- Levels of confidence of benefit and cost information as determined by probabilistic analysis. The effects of varying the values of key assumptions should also be tested.

5.4 GENERIC METHODOLOGY FOR ASSESSING CAPABILITIES OF SPECIFIC SYSTEMS TO MEET A-SMGCS REQUIREMENTS

5.4.1 Introduction

5.4.1.1 The assessment of specific technologies should preferably use a standardized methodology so as to have a baseline reference for each technology that will be assessed. The assessment is an iterative process, which should take place in close cooperation between those involved, i.e. authorities, service providers, operators and manufacturers.

5.4.1.2 The feasibility of application of various technologies and systems should be proven by a feasibility assessment, which determines whether a selected technology meets the requirements. This feasibility assessment could comprise various techniques, such as theoretical analysis, simulation or, simply, data collection.

5.4.1.3 If the assessment takes place according to a standardized methodology, the documented results of the assessment could serve as an element of a certification process and as evidence of the performance of the system or part thereof up to the operational requirement.

5.4.2 Generic technology assessment methodology

5.4.2.1 The information flow in the assessment process is illustrated in Figure 5-1. Important first steps include the definition of the technology to be assessed, the specific architecture of this technology, and the role (e.g. the guidance function) that this technology is proposed to fulfil in the A-SMGCS. It is possible that this architecture may change during the assessment process as difficulties in satisfying certain requirements become apparent. When such a change occurs, it is important to document the revised architecture completely and restart the assessment process from the beginning.

5.4.2.2 In documenting the technology, architecture and role in the A-SMGCS to be assessed, a tabular format may be useful to support the text.

5.4.3 Generic assessment parameters

The operational and performance requirements for the A-SMGCS should be broken down into quantitative performance parameters and qualitative design guidelines. Where available, a metric has been associated with each performance parameter. The resulting generic matrix is intended to provide the basis for assessing a technology which is proposed for application in the A-SMGCS.

5.5 SAFETY ASSESSMENT

5.5.1 Introduction

5.5.1.1 Before an A-SMGCS is declared operational, a safety assessment should be made in order to understand the safety impact caused by the application of the system and also the safety impact in case of failure of elements of the system. The safety assessment should be supported by relevant documentation, which should be in a format that enables easy updating after system modification. The documentation should clearly indicate against which safety objectives the assessment took place and if these objectives were fully met.

5.5.1.2 The safety assessment is not only meant to convince the authority of the safety of the system but also to clearly indicate aspects like training and controls upon which the safety depends so that the required safety level can be maintained.

5.5.2 System description

In order to perform a safety assessment, a portrayal of the total system is required. This portrayal starts with a description of the system to be assessed. This description should include:

a) the intended functions of the system including its modes of operation;

b) the system performance parameters and their allowable limits (e.g. what constitutes a failure);

c) the functional and physical boundaries of the system and its components;

d) the environmental conditions which the system needs to withstand;

e) the interfaces with other systems and with human operators (controllers, pilots and vehicle drivers); and

f) functional block diagrams of the system and its interfaces.

5.5.3 Hazard analysis

5.5.3.1 The hazard analysis should indicate what constitutes a failure condition of the system. The hazard analysis should focus on the functions and vulnerabilities of the system and include:

a) the consequences of a failure of an A-SMGCS or a part thereof to function within its specified performance limits;

b) the consequences of other possible malfunctions of the system and their effects on other systems;

c) the consequences to an A-SMGCS of failures in other systems;

d) the identification of possible common-mode or cascade failures (e.g. a failure of a guidance system that causes several aircraft to loose their guidance); and

e) the identification of possible sources for errors by human operators.

5.5.3.2 The result of the hazard analysis may well be an indication of the need for a system (or part thereof) redesign.

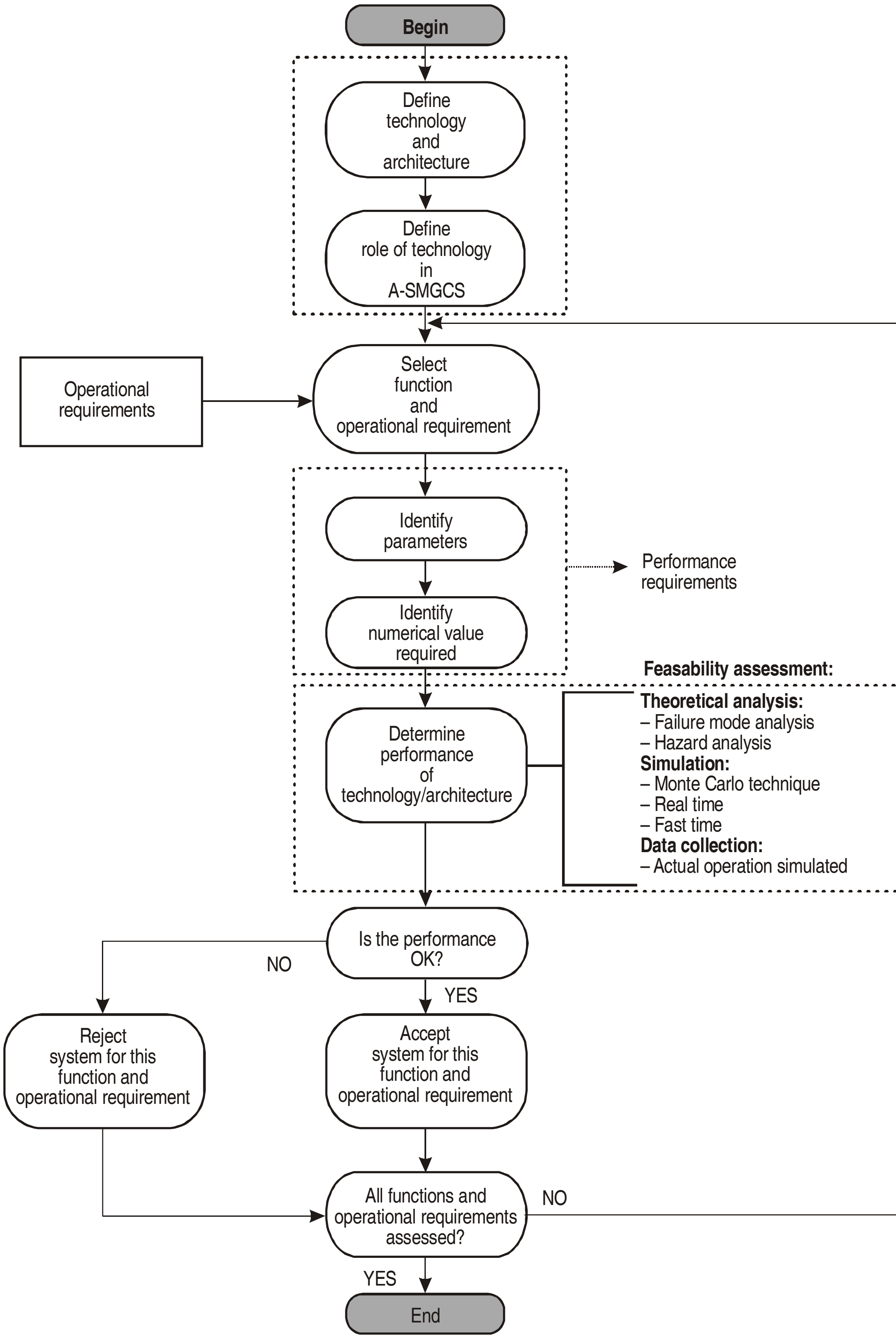


Figure 5-1. Flow diagram of generic technology assessment methodology

5.5.4 Failure mode analysis

A failure analysis of the total system is needed to demonstrate compliance with the operational requirements.

5.5.5 Risk allocation

It is necessary to indicate the probability of failure of each element of the A-SMGCS in order to ensure a proper assessment of the overall safety of the system.

5.5.6 Example of safety assessment methodology

5.5.6.1 Each procedure developed for use with an A-SMGCS should undergo a generic safety or risk assessment. However, the implementation of the procedures at an aerodrome should require a site-specific risk assessment to ensure that all local safety issues are addressed. One method of conducting such a risk assessment is described in the following paragraphs.

5.5.6.2 Risk assessments should be performed prior to a change to an existing procedure or the introduction of a new procedure, system or type of equipment. The risk assessment should assess all functions and systems, and changes to them, for their safety significance. Any risks identified during system introduction should be consistent with the level of safety established for that procedure, system or equipment. The methodology used and the results should be fully documented and preferably presented by the service provider to the safety regulator for approval.

5.5.6.3 The level of risk for any failure in a function can be derived from, and associated with, maximum allowable rates of occurrence. The final step is to identify the tools or techniques that need to be applied to the specification, design and testing of the procedures or systems to provide the required safety assurance.

5.5.6.4 To tolerate a risk means that it is not regarded as negligible or something that might be ignored, but rather as something that needs to be monitored and reduced if possible.

Risk assessment process

5.5.6.5 The generic risk assessment process is as follows:

a) identify possible safety hazards that could arise, including the failure of any relevant procedure, system or equipment;

b) classify the risk of the identified safety hazard in terms of probability of occurrence and the criticality of effect on aircraft;

c) assess if the risk of the identified safety hazard is tolerable; and

d) if the risk is not tolerable, establish mitigating action.

5.5.6.6 The methodology used and the results of the risk assessment process should be compiled in a report, which should also describe the new system, procedure or amendment. For each significant risk that is determined, a rationale or "argument" for the tolerability of the risk, and the details of any mitigation used should be provided. The report should also outline the management process whereby safety is monitored and managed. The report should be submitted to the safety regulator for assessment/approval.

Risk classification

5.5.6.7 In order to ensure that the risk assessment is valid, it is necessary to have a set of appropriate and consistently applied definitions of probability of occurrence and criticality.

5.5.6.8 Risk classification models are already in use in many safety-related industries. Probability of occurrence definitions and safety criticality categories used by some States are presented in Table 5-5 and Table 5-6 respectively. Other models may be used with the agreement of the safety regulator.

Note 1.— Some risks are dependent on the number of hours that an aircraft is exposed to risk (per flight hour), and the duration of a flight has an effect on the risk. Thus, the term "per hour" is employed. For aerodrome operations, it is usually more appropriate to use "per operation" as system functionality is normally not time-dependent.

Note 2.— The probability of occurrence is defined in both qualitative and quantitative terms. In certain applications a numerical analysis may not be practical, e.g. the rate of failure of a human cannot be expressed numerically with confidence. Also, qualitative assessment may be sufficient for events classified as minor or major.

Table 5-5. Probability of occurrence definitions

Probability of occurrence classification	Extremely improbable	Extremely remote	Remote	Probable
Quantitative definition	$< 10^{-9}$ per flight hour	10^{-7} to 10^{-9} per flight hour	10^{-5} to 10^{-7} per flight hour	1 to 10^{-5} per flight hour
Qualitative definition	Should virtually never occur in the whole fleet life	Unlikely to occur when considering several systems of the same type but, nevertheless, has to be considered as being possible	Unlikely to occur during total operational life of each system but may occur several times when considering several systems of the same type	May occur once or several times during operational life

Table 5-6. Safety criticality classification

Category	Catastrophic	Hazardous	Major	Minor
Results in one or more of the following effects	• The loss of the aircraft • Multiple fatalities	• A large reduction in safety margins • Physical distress or a workload such that the flight crew cannot be relied on to perform their tasks accurately or completely • Serious injury or death of a relatively small proportion of the occupants	• A significant reduction in safety margins • A reduction in the ability of the flight crew to cope with adverse operating conditions as a result of increase in workload or as a result of conditions impairing their efficiency • Injury to occupants	• Nuisance • Operating limitations • Emergency procedures

Risk tolerability matrix

5.5.6.9 A risk tolerability matrix defines the maximum rate of occurrence allowed for any particular effect or event. An example is shown in Table 5-7.

Note 1.— Minor effects are not usually a concern in certification but may well be unacceptable commercially or operationally.

Note 2.— Table 5-7 shows the minimum safety performance standards that may be applied.

5.6 CERTIFICATION

5.6.1 All ground equipment that forms an essential element of an A-SMGCS should be certified for its use and be regularly inspected or reviewed. The aerodrome operator should have certified maintenance procedures established for the ground equipment that is essential to the performance of an A-SMGCS.

5.6.2 The certification of airborne equipment should be covered by aircraft certification procedures.

5.6.3 All software used for an A-SMGCS should be certified through a standard software certification procedure.

5.6.4 Any new application or change to an A-SMGCS should be evaluated by the regulatory authority for compliance of the system with the operational requirements. The evaluation should be followed by a formal approval. Additional requirements or limitations of the operational use could be stated.

5.6.5 The aerodrome operator and the ATC service provider are responsible for the training and maintenance procedures for personnel and equipment under their jurisdiction. In the certification process, they should be able to demonstrate that they can perform all tasks required for the proper functioning of an A-SMGCS.

5.6.6 The manufacturer of an A-SMGCS is responsible for the proper documentation of the system concept and design. Furthermore, evidence of system capabilities should be provided. Depending on the local situation, the manufacturer could have to deal with either the regulatory authority or the purchasing organization.

Table 5-7. Risk tolerability matrix

<table>
<tr><td>Quantitative probability of occurrence</td><td colspan="5">1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9}</td></tr>
<tr><td>JAR 25
Qualitative probability of occurrence</td><td>Frequent</td><td>Reasonably probable</td><td>Remote</td><td>Extremely remote</td><td>Extremely improbable</td></tr>
<tr><td>Classification of effect</td><td colspan="2">Minor</td><td>Major</td><td>Hazardous</td><td>Catastrophic</td></tr>
</table>

Appendix A

A-SMGCS CATEGORIZATION

1. INTRODUCTION

1.1 For guidance on what level of A-SMGCS is appropriate to a specific aerodrome, it is necessary to consider:

a) visibility conditions;

b) traffic density; and

c) aerodrome layout.

1.2 The criteria proposed for visibility conditions and traffic density are based on the *Manual of Surface Movement Guidance and Control Systems (SMGCS)* (Doc 9476).

2. VISIBILITY CONDITIONS

2.1 Whereas Doc 9476 (Chapter 2) lists three visibility conditions for the purpose of discussing SMGCS, a further breakdown of low visibility conditions has been included here. For the purpose of this manual, visibility conditions are subdivided and defined as follows:

a) Visibility condition 1:

   Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, and for personnel of control units to exercise control over all traffic on the basis of visual surveillance;

b) Visibility condition 2:

   Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance;

c) Visibility condition 3:

   Visibility sufficient for the pilot to taxi but insufficient for the pilot to avoid collision with other traffic on taxiways and at intersections by visual reference, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. For taxiing, this is normally taken as visibilities equivalent to an RVR of less than 400 m but more than 75 m; and

d) Visibility condition 4:

   Visibility insufficient for the pilot to taxi by visual guidance only. This is normally taken as an RVR of 75 m or less.

Note.— The above visibility conditions apply for both day and night operations.

2.2 When selecting A-SMGCS modules for a particular aerodrome, in addition to the main criteria described above, effects of short-term transitory factors, such as low angle sun glare, twilight, and differing day and night viewing conditions, should be considered.

2.3 Aerodrome movement rates may include short-term peak loads in excess of normal movement rates. This may result in difficulties for ATC to maintain awareness of the traffic situation by visual means alone.

3. TRAFFIC DENSITY

3.1 Traffic density is measured from the mean busy hour independent of visibility condition.

3.2 Traffic density is divided into three categories:

a) Light (L):

No more than 15 movements per runway or typically less than 20 total aerodrome movements;

b) Medium (M):

16 to 25 movements per runway or typically between 20 to 35 total aerodrome movements; and

c) Heavy (H):

26 or more movements per runway or typically more than 35 total aerodrome movements.

4. AERODROME LAYOUT

For aerodrome layout, three levels have been established as follows:

a) Basic (B):

An aerodrome with one runway, having one taxiway to one apron area;

b) Simple (S):

An aerodrome with one runway, having more than one taxiway to one or more apron areas; and

c) Complex (C):

An aerodrome with more than one runway, having many taxiways to one or more apron areas.

5. AERODROME TYPES

5.1 By identifying each of the appropriate criteria, it is possible to determine the necessary SMGCS or A-SMGCS modules to support the operational requirements at a specific aerodrome based on the intended minimum visibility for operations.

5.2 Considering the criteria at 2.1, 3.2 and 4 in this appendix, there are 36 combinations which may be related to an aerodrome type. These can be grouped for each visibility condition as shown in Table A-1.

Table A-1. Combination of aerodrome types

Visibility condition	1	2	3	4
Aerodrome type	T-1:(B)(L) T-2:(B)(M) T-3:(B)(H) T-4:(S)(L) T-5:(S)(M) T-6:(S)(H) T-7:(C)(L) T-8:(C)(M) T-9:(C)(H)	T-10:(B)(L) T-11:(B)(M) T-12:(B)(H) T-13:(S)(L) T-14:(S)(M) T-15:(S)(H) T-16:(C)(L) T-17:(C)(M) T-18:(C)(H)	T-19:(B)(L) T-20:(B)(M) T-21:(B)(H) T-22:(S)(L) T-23:(S)(M) T-24:(S)(H) T-25:(C)(L) T-26:(C)(M) T-27:(C)(H)	T-28:(B)(L) T-29:(B)(M) T-30:(B)(H) T-31:(S)(L) T-32:(S)(M) T-33:(S)(H) T-34:(C)(L) T-35:(C)(M) T-36:(C)(H)

Note.— Appendix B shows a grouping of the aerodrome types appropriate to the level of implementation of A-SMGCS after considering the necessary functional requirements to maintain A-SMGCS capacity.

Appendix B

A-SMGCS IMPLEMENTATION LEVELS

Criteria for the categorization of aerodromes on the basis of visibility conditions, traffic density and aerodrome layout are given in Appendix A. The appropriate level of functional implementation of an A-SMGCS at a particular aerodrome can be determined by identifying the criteria that apply. There are 36 possible aerodrome type criteria combinations, 4 functional criteria (surveillance, control, routing and guidance) and 3 user groups (controller, pilot/vehicle driver and system) to consider. Overall, the number of options is too large to be of practical assistance to anyone tasked with defining the level of implementation that is appropriate for a given aerodrome. Table B-1 is an example of one means of grouping A-SMGCS implementation into 5 levels that together cover all cases. The table shows that the 4 basic functions are provided at all levels. Within the table, the role played by automation and avionics increases progressively through the levels. Level V corresponds to the most demanding aerodrome requirements where the level of automation is the highest.

Table B-1. Criteria for determining A-SMGCS implementation levels

Aerodrome type	*User*	*Surveillance*	*Control*			*Routing*	*Guidance*					*Level*
			Conflict prediction and/or detection	*Conflict analysis*	*Conflict resolution*		*Ground*				*On board*	
							*1	*2	*3	*4		
T-1: 1:(B)(L) T-2: 1:(B)(M) T-3: 1:(B)(H) T-4: 1:(S)(L)	Controller	X	X	X	X	X						I
	Pilot/Vehicle driver		X	X	X		X					
	System											
T-5: 1:(S)(M) T-6: 1:(S)(H) T-7: 1:(C)(L) T-10: 2:(B)(L) T-11: 2:(B)(M) T-13: 2:(S)(L)	Controller	X	X	X	X	X						II
	Pilot/Vehicle driver		X	X	X		X	X				
	System	X	X									

Aerodrome type	*User*	*Surveillance*	*Control*			*Routing*	*Guidance*					*Level*
			Conflict prediction and/or detection	*Conflict analysis*	*Conflict resolution*		*Ground*				*On board*	
							*1	*2	*3	*4		
T-8: 1:(C)(M) T-12: 2:(B)(H) T-14: 2:(S)(M) T-16: 2:(C)(L) T-19: 3:(B)(L) T-20: 3:(B)(M) T-22: 3:(S)(L)	Controller		X	X	X				X			III
	Pilot/Vehicle driver		X	X 1)	X 1)		X					
	System	X	X	X	X	X						
T-9: 1:(C)(H) T-15: 2:(S)(H) T-17: 2:(C)(M) T-18: 2:(C)(H) T-21: 3:(B)(H) T-23: 3:(S)(M) T-24: 3:(S)(H) T-25: 3:(C)(L) T-26: 3:(C)(M) T-27: 3:(C)(H)	Controller		X	X	X							IV
	Pilot/Vehicle driver		X	X 1)	X 1)		X					
	System	X	X	X	X	X				X		
T-28: 4:(B)(L) T-29: 4:(B)(M) T-30: 4:(B)(H) T-31: 4:(S)(L) T-32: 4:(S)(M) T-33: 4:(S)(H) T-34: 4:(C)(L) T-35: 4:(C)(M) T-36: 4:(C)(H)	Controller		X	X	X							V
	Pilot/Vehicle driver						X				X	
	System	X	X	X	X	X				X		

*1. Painted centre line and taxiway guidance signs
*2. Fixed centre line lights
*3. Manual switched centre line lights
*4. Automatic switched centre line lights

Note 1.— Does not apply in visibility condition 3.

Appendix C

EQUIPMENT EVOLUTION FOR A-SMGCS

Since A-SMGCS are in the early stages of their research and development, the material in this appendix should only be used as a guide. It should not be used to justify technical specifications. For each of the possible 36 aerodrome types, Table C-1 indicates the types of equipment that may be needed to provide the required level of service for each of the 4 basic A-SMGCS functionalities. For some of the requirements, equipment has already been fully developed and is in service. In other cases, potentially suitable equipment has been developed, its technical performance has been demonstrated, and it may soon be in service. In yet other cases, equipment research and development are at early stages. It is important to recognize that equipment evolution and operational procedures for A-SMGCS will be strongly influenced by the need for operational safety and efficiency, and the results of tests and evaluations that are currently in hand or planned for the future. Table C-1 is provided purely for illustrative purposes.

Table C-1. Equipment evolution for A-SMGCS

Aerodrome type			Visibility	Surveillance system										Routing system		Guidance system			Control system							
				Approach		Manoeuvring area				Apron									Conflict			Movement	Incursion alerts		Protection	
	Layout	Traffic level		Visual	Instrument	Detection	Tracking	Identification	Accurate	Detection	Tracking	Identification	Accurate	Route	Route planning	Visual aids	Situation awareness	Restricted area	Detection	Alert	Resolution		Runway	Taxiway	Runway	Taxiway
1	B	L	1											ATCO	ATCO	P	C								H,C	H,C
2	B	M	1											ATCO	ATCO	P	C								H,C	H,C
3	B	H	1	R	R									ATCO	ATCO	P	C								H,C	H,C
4	S	L	1											ATCO	ATCO	P	C								H,C	H,C
5	S	M	1			SMR								ATCO	ATCO	P	C		(✓)						H,C	H,C
6	S	H	1	R	R	✓	✓							ATCO	ATCO	P	C		(✓)				(✓)	(✓)	H,C	H,C
7	C	L	1		R	SMR								ATCO	ATCO	P	C		(✓)						H,C	H,C
8	C	M	1		R	✓	✓							ATCO	Sys	M	C		(✓)				(✓)	(✓)	H,C	H,C
9	C	H	1	R	R	✓	✓							Sys	Sys	A	C		✓	✓	✓		✓	✓	H,C	H,C
10	B	L	2		R	SMR								ATCO	ATCO	P	C		(✓)			(✓)	✓	✓	H,C,G	H,C
11	B	M	2		R	SMR								ATCO	ATCO	P	C		(✓)			(✓)	✓	✓	H,C,G	H,C
12	B	H	2	R	R	✓	✓							ATCO	Sys	M	C		(✓)			(✓)	✓	✓	H,C,G	H,C
13	S	L	2		R	SMR								ATCO	ATCO	P	C		(✓)			(✓)	✓	✓	H,C,G	H,C
14	S	M	2		R	✓	✓	✓						ATCO	Sys	M	C		(✓)			(✓)	✓	✓	H,C,G	H,C
15	S	H	2	R	R	✓	✓	✓						Sys	Sys	A	C		✓	✓	✓	(✓)	✓	✓	H,C,G	H,C
16	C	L	2		R	✓	✓	✓						ATCO	Sys	M	C		(✓)			(✓)	✓	✓	H,C,G	H,C
17	C	M	2		R	✓	✓	✓						Sys	Sys	A	C		✓	✓	✓	(✓)	✓	✓	H,C,G,S	H,C,T
18	C	H	2	R	R	✓	✓	✓						Sys	Sys	A	C		✓	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
19	B	L	3		R	✓	✓	✓		✓				ATCO	Sys	M	C		(✓)	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
20	B	M	3		R	✓	✓	✓		✓				ATCO	Sys	M	C		(✓)	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
21	B	H	3		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A	C		✓	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
22	S	L	3		R	✓	✓	✓		✓	✓			ATCO	Sys	M	C		(✓)	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
23	S	M	3		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A	C		✓	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
24	S	H	3		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A	C		✓	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
25	C	L	3		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A	C		✓	✓	✓	✓	✓	✓	H,C,G,S	H,C,T
26	C	M	3		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A	C		✓	✓	✓	✓	✓,E	✓,E	H,C,G,S	H,C,T
27	C	H	3		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A	C		✓	✓	✓	✓	✓,E	✓,E	H,C,G,S	H,C,T
28-36	All	All	4		R	✓	✓	✓	✓	✓	✓	✓	✓	Sys	Sys	A,E	C,E	E	✓	✓	✓	✓,E	✓,E	✓,E	H,C,G,S,E	H,C,T,E

Aerodrome types:

Layout	B = Basic
Layout	S = Simple
Layout	C = Complex
Traffic	L = Light
Traffic	M = Medium
Traffic	H = Heavy

System Modules:

R	Approach radar
SMR	Surface movement radar [1)]
P	Painted centre line with/without lights [1)]
M	Manually switched (block of) centre line lights [1)]
A	Automatic switched centre line lights
C	Aerodrome chart and signs [1)]
H	Holding position marking [1)]
G	Runway guard lights [1)]
S	Switched stop bar [1)]
T	Traffic lights
ATCO	Air traffic controller
Sys	System
✓	New development required
(✓)	New development desirable
E	Enhanced cockpit display

Note 1.— For details see Table 2-2 of Doc 9476.

Appendix D

TARGET LEVEL OF SAFETY (TLS)

1. INTRODUCTION

This appendix provides details on the background information that was used to determine the A-SMGCS target level of safety (TLS). It is necessary to allocate a portion of the TLS for an entire flight (one accident per 10^7 operations) to the A-SMGCS taxi phase. The method chosen to determine an appropriate TLS for an operation was to base it on the historical accident and movement rates within the European Civil Aviation Conference (ECAC) area. A similar exercise conducted in the United States is also outlined. Both produce comparable results.

2. ECAC ACCIDENT DATA

2.1 The ECAC study was based on the ICAO "Accident/Incident Data Reporting" (ADREP) system database and the number of movements on ECAC aerodromes extracted from ICAO statistics yearbooks (Civil Aviation Statistics of the World (Doc 9180)). Flight data from the EUROCONTROL Central Flight Management Unit (CFMU) were used to analyse the number of movements but, since this information refers to flights since 1992, it was only used as reference information.

2.2 The ADREP database was used to collect the number and characteristics of ground movement accidents in ECAC member States from 1980 to 1999. During this time period, there were 627 recorded accidents from 27 ECAC States; of which 52 accidents were fatal or caused total aircraft destruction. The other 575 accidents, even if they had serious consequences or were "near-misses", were not included in the study. Of the 52 fatal or hull-loss accidents, 2 occurred as a result of taxi or runway operations.

2.3 From 1980 to 1996, there were 150 612 893 movements in the ECAC area. However, data have yet to be published for the period 1997 to 1999; therefore, an annual growth of 5 per cent was estimated. Since the data refers to principal aerodromes only, a factor of 10 per cent was applied to the total number of aircraft movements to take into consideration the traffic at non-principal aerodromes. This gives a total number of movements of 165 674 182.

2.4 The above data give an ECAC-wide taxi accident rate of 2/165 674 182 = 1.2×10^{-8} per operation. If we consider that the average taxi time of an aircraft does not exceed 6 minutes, the risk per hour will be 1.2×10^{-6} per hour. This value compares with a similar analysis, conducted in the United States for A-SMGCS TLS using worldwide and United States accident data, which is outlined below.

3. WORLDWIDE AND UNITED STATES ACCIDENT DATA

3.1 An analysis to determine a TLS for A-SMGCS that was performed by a sub-group of the ICAO All Weather Operations Panel in 1997 considered accident data for the landing and taxi phases of flight and compared the calculated risk of a fatal accident within the global aerodrome operations TLS of 10^7.

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3.2 An analysis of worldwide accident data from 1985 to 1994 revealed that the fatal accident rate was 1.8×10^{-6} per operation and that taxi accidents accounted for 5 per cent of fatal accidents. Therefore, the worldwide fatal taxi accident rate was 9.0×10^{-8} per operation.

3.3 An analysis of National Transportation Safety Board (NTSB) data from 1985 to 1994 revealed that the fatal accident rate was 0.56×10^{-6} per operation and that fatal taxi accidents accounted for 11 per cent of all fatal accidents. Therefore, the United States fatal taxi accident rate was 6.2×10^{-8} per operation.

3.4 The total TLS defined in developing the approach and landing required navigation performance (RNP) was 1.5×10^{-7} per mission. The final approach and landing allocation was 1.0×10^{-8} per operation.

3.5 The TLS for A-SMGCS, encompassing the taxi phase of the total flight operations, must fit within this overall mission TLS. Another factor is that the accident data reflect accidents due to all causes, whereas A-SMGCS-related accidents would constitute only a portion of taxi accidents. Therefore, the A-SMGCS TLS should not receive the entire allocation of risk related to the taxi phase of operation.

3.6 As can be seen from the worldwide accident data and the NTSB data for aircraft operations in the United States, the fatal taxi accident rates are similar (9.0 vs. 6.2×10^{-8} per operation). As stated before, the total mission TLS is targeted to be 1.0×10^{-7}. The final approach and landing phase was allocated at 1.0×10^{-8}. Similarly, the other phases of flight have allocations that use only a small portion of the overall TLS. Therefore, the taxi phase should be allocated a comparable portion. Based on the above considerations, the A-SMGCS TLS is 1.0×10^{-8} per operation. Although the data used in the evaluation were collected during the same time period, it was considered that the margin of 6 to 9 over the historical accident rate is in line with the allocations of TLS to the various phases of flight used for the approach and landing RNP and, therefore, may be considered a fair conclusion.

Appendix E

A-SMGCS RESEARCH

1. INTRODUCTION

1.1 This appendix looks at some of the A-SMGCS that have been the subject of research projects or operational trials in Europe and the United States.

1.2 The purpose of this appendix is not only to describe A-SMGCS but to provide some information on the type of components or sub-systems that may be used to develop an A-SMGCS suitable for an individual aerodrome.

2. DEMONSTRATION FACILITIES FOR AERODROME MOVEMENT MANAGEMENT (DEFAMM)

2.1 The Demonstration Facilities for Aerodrome Movement Management (DEFAMM) was a research project that was carried out by fifteen European partners from industry, research institutes, and aerodrome and ATC authorities, and was sponsored by the European Commission[1]. In DEFAMM, various prototype sub-systems covering all the main functions of an A-SMGCS were demonstrated in operational environments, including four European aerodromes. This was the first large-scale integrated system demonstration for aerodrome surface traffic management on a European level. The project commenced on 1 December 1995 and ended on 31 March 1999.

2.2 Four aerodromes participated in the demonstration of the A-SMGCS. Not all of the functions were implemented at each demonstration site. This was because the total range of the DEFAMM functions formed a complex system, and a single test site, being also an operational aerodrome, would have been completely overloaded. Furthermore, it was desirable to demonstrate that an A-SMGCS could be profitably embedded in different environments with a variety of aerodrome facilities and topological constraints. A further advantage was the ability to use several independent test environments for systems such as positioning reference and digitized aerodrome maps.

2.3 DEFAMM functional demonstration

Surveillance function

2.3.1 As the architecture in Figure E-1 shows, the surveillance function was realized by two non-cooperative sensors and two cooperative sensors. The two non-cooperative sensors were the existing surface movement radar (SMR) with the new radar data extractor electronic scanning radar directly delivering digital target reports. The two cooperative sensors comprised the prototype Mode S multilateration system with a Mode S central station (mainly for aircraft detection and identification) and a differential global navigation satellite system (D-GNSS) sub-system with a D-GNSS central station (mainly for vehicles). A cooperative sensor for vehicles was also demonstrated to enhance the surveillance capabilities.

2.3.2 The sensor data fusion was implemented on the sensor data processing, which combined the four sensor types and used data from the aerodrome surveillance radar (ASR) to deliver a unique picture of the traffic situation. The sensor data fusion is a software product, and its task is to track and filter the surveillance data, to provide identification information of controlled vehicles and to monitor the traffic situation.

Control function

2.3.3 The sub-system for conflict handling was realized on a workstation of the sensor data processing computers. The main functions implemented were the detection and handling of:

1. European Commission DG VII: Air Transport/Airports/Task 4.3.1/44.

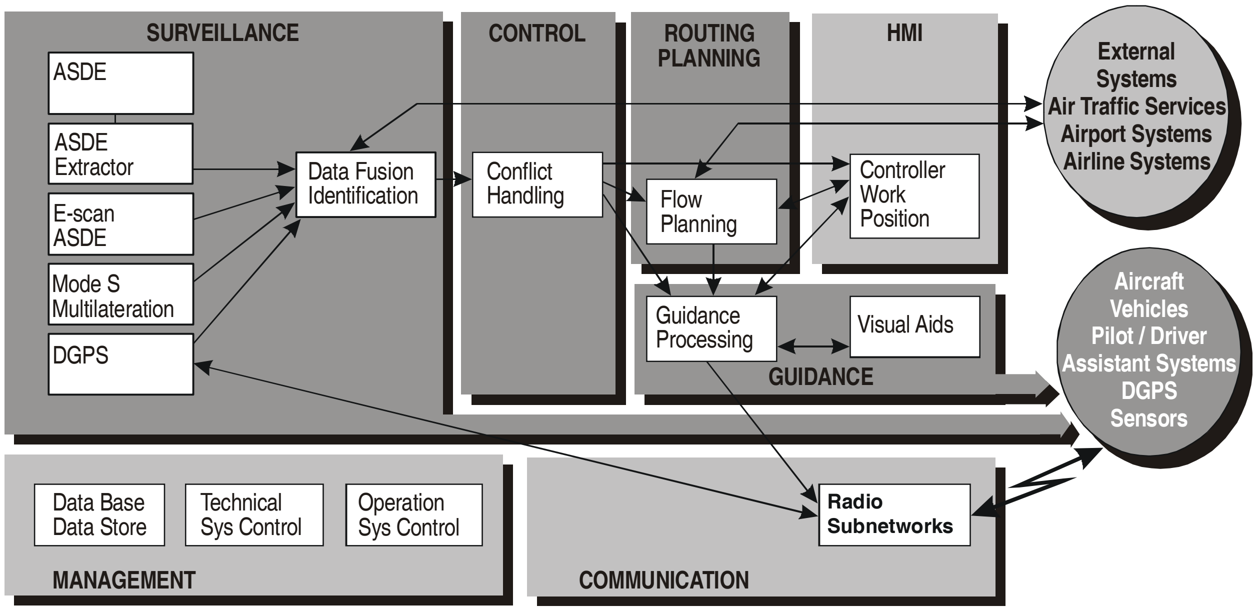

Figure E-1. DEFAMM functional architecture

a) area violation and intrusion;

b) runway incursion;

c) crossing conflicts;

d) roll-up and opposite traffic conflicts;

e) deviation from assigned route; and

f) deviation from assigned time slots.

Planning function

2.3.4 The following basic planning functions were implemented:

a) proposed movement plans (routes and time slots) provided to the controller for:

   1) arriving aircraft when at final approach;

   2) departing aircraft after start-up request; and

   3) selected aircraft or vehicle on request;

b) the means to edit and modify the plans at any time in terms of:

   1) route change for new destination;

   2) route change for the same destination; and

   3) change of plans with respect to new time slots;

c) the means to negotiate the plans with the controller, i.e.:

   1) issue plan proposals to the HMI;

   2) change status when the plan is accepted by the controller; and

   3) change status when the plan is cleared by the controller; and

d) cleared plans to the guidance processing function.

Guidance function

2.3.5 The guidance processor permitted:

a) manual or automated switching of centre line light segments and stop bars according to the taxi plan and the current situation of the aircraft or vehicles; and

b) clearance negotiation and automated transmission of taxi plan and guidance commands via data link and the on-board display system.

2.3.6 Guidance with the aerodrome ground lighting was implemented to:

a) guide the aircraft or vehicles according to the route of the cleared plan with selectively switchable taxiway centre line lights;

b) allow manual switching of the taxiway centre line lights; and

c) allow manual switching of the stop bars.

2.3.7 Guidance with the on-board display (pilot/driver assistance system) was implemented to:

a) display the aircraft's/vehicle's own position on the aerodrome with respect to the assigned route;

b) support the negotiation of taxi plans (e.g. request clearance, receive clearance and accept clearance); and

c) display the cleared movement plan (e.g. taxi route and time slots).

2.3.8 An addressable sign that was able to visually display the correct route was tested at a complex junction where six taxiways converged. At this junction, some pilots would slow down or stop in order to find their taxi route. The aim of the addressable sign was to improve the taxiing efficiency. The signs were remotely controlled by ATC via the A-SMGCS. The aircraft's call sign and the parking destination were displayed on the left screen while the intended taxi route was displayed graphically on the right display (see Figure E-2).

Communication function

2.3.9 The communication function comprised a time division multiple access (TDMA) VHF data link sub-network and performed the following three main tasks:

1. Every second, it transmitted the D-GNSS position reports of the equipped aircraft or vehicles to the surveillance function;

2. It distributed the D-GNSS correction information to the aircraft or vehicles; and

3. It exchanged data for the on-board guidance (i.e. clearance negotiation and transmission of cleared movement plans).

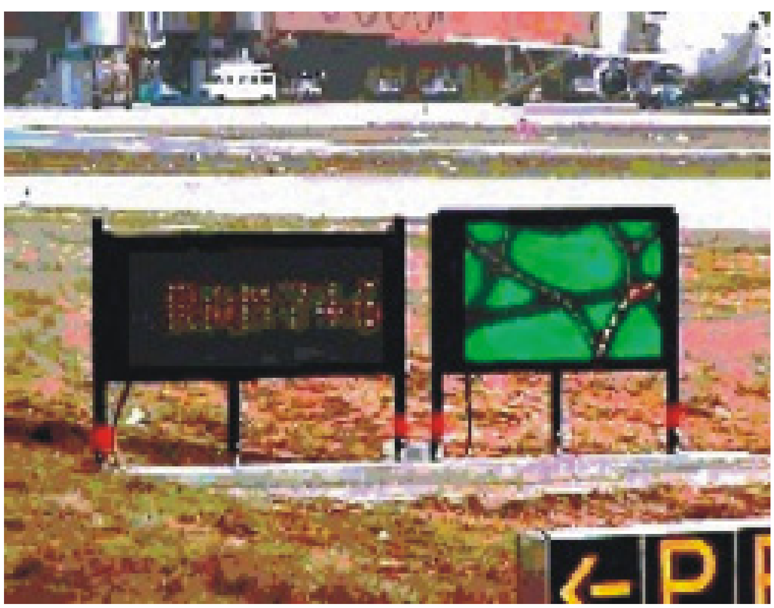

Figure E-2. Addressable sign on test during the DEFAMM functional demonstration

Human-machine interface (HMI)

2.3.10 Two different types of HMIs were provided: a controller working position (CWP) and the HMI of the pilot/driver assistance system (PDAS). The CWP consisted of two visual display units that displayed the current traffic situation. One screen was used to enlarge a particular portion of the surveyed area.

2.3.11 The negotiation of taxi plans was supported by entering a clearance request via predefined keys on an on-board display, which was then transmitted via data link to the ground system. The received clearances were displayed on the screen of the PDAS. Approved movement plans were displayed on the screen as a taxi route, with time slots at waypoints. The positions of the aircraft or vehicle and other equipped aircraft or vehicles were also displayed on the PDAS screen.

3. OPERATIONAL BENEFIT EVALUATION BY TESTING AN A-SMGCS (BETA PROJECT)

3.1 The BETA project was also funded by the European Commission from 2000 to 2001. The project involved the operational testing of system components (based on early drafts of this manual) installed at three European airports. The systems comprised surveillance sensor equipment and computers from different manufacturers integrated with the existing airport and ATC equipment and infrastructure to provide the first full-scale implementation of A-SMGCS within Europe (see Figure E-3).

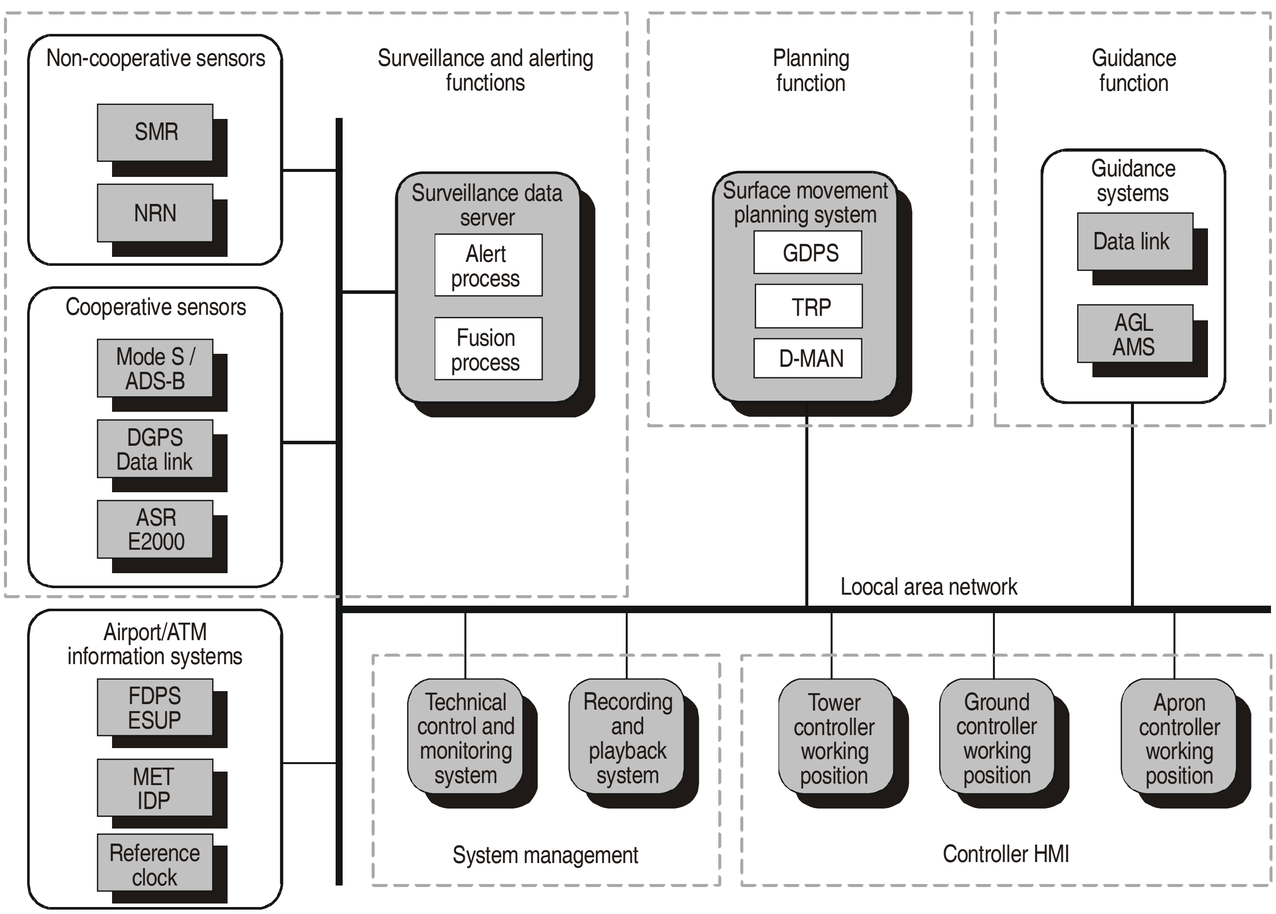

Figure E-3. BETA functional architecture

3.2 The system testing covered the following aspects:

a) surveillance:

1) detection and presentation of traffic and obstacles on the aerodrome movement area and approaches;

2) automatic identification of suitably equipped cooperating traffic, including arriving aircraft;

3) departing aircraft, if equipped with active Mode S transponders;

4) participating vehicles (data link equipped test vans and service vehicles); and

5) manual identification of other targets;

b) alerting:

1) runway occupied/runway incursion alerting for arrivals and departures;

2) restricted area intrusion alerting;

3) crossed stop bar alerting; and

4) route deviation alerting;

c) planning:

1) flight plan presentation;

2) creation, modification and editing of flight plans (including VFR and vehicles);

3) electronic flight strips;

4) handover;

5) departure sequence proposal; and

6) selection of taxiway route;

d) guidance:

1) stop bars;

2) on-board guidance;

3) clearance delivery; and

4) route indication; and

e) controller HMI:

1) traffic situation display; and

2) planning display.

3.3 The BETA equipment was provided in a non-redundant configuration, focusing on data integrity, accuracy and usability.

4. FAA RUNWAY INCURSION REDUCTION PROGRAMME

4.1 In 2000, trials started in the United States under the FAA Runway Incursion Reduction Programme (RIRP)[2] to evaluate new technologies for A-SMGCS.

4.2 RIRP surveillance system

Figure E-4 shows a block diagram of the RIRP surveillance system. At the heart of the system is the surface surveillance data server (SSDS). The SSDS receives surveillance and flight plan information from a variety of sources and "fuses" the information into one optimal report for user display. The surveillance information comes from a variety of cooperative and non-cooperative sensors, including terminal and surface radar, inductive loops, automatic dependent surveillance — broadcast (ADS-B), and multilateration. The flight plan information is received from the local automation system, an automated radar terminal system (ARTS), via the flight plan unit. The majority of information is passed between sub-systems over the LAN. It is expected that the system will be modular to meet the surveillance requirements of various aerodromes in the United States.

4.3 Sensor inputs

The RIRP prototype demonstration system will accept various surveillance inputs, including the following:

a) ASDE-3: The ASDE-3 is a primary radar intended for aerodrome surface surveillance. It maintains a

2. "1998 Airport Surface Operations Safety Plan to Prevent Runway Incursions and Improve Surface Operations", Runway Incursion Program Office (ATO-102), FAA; 1998.

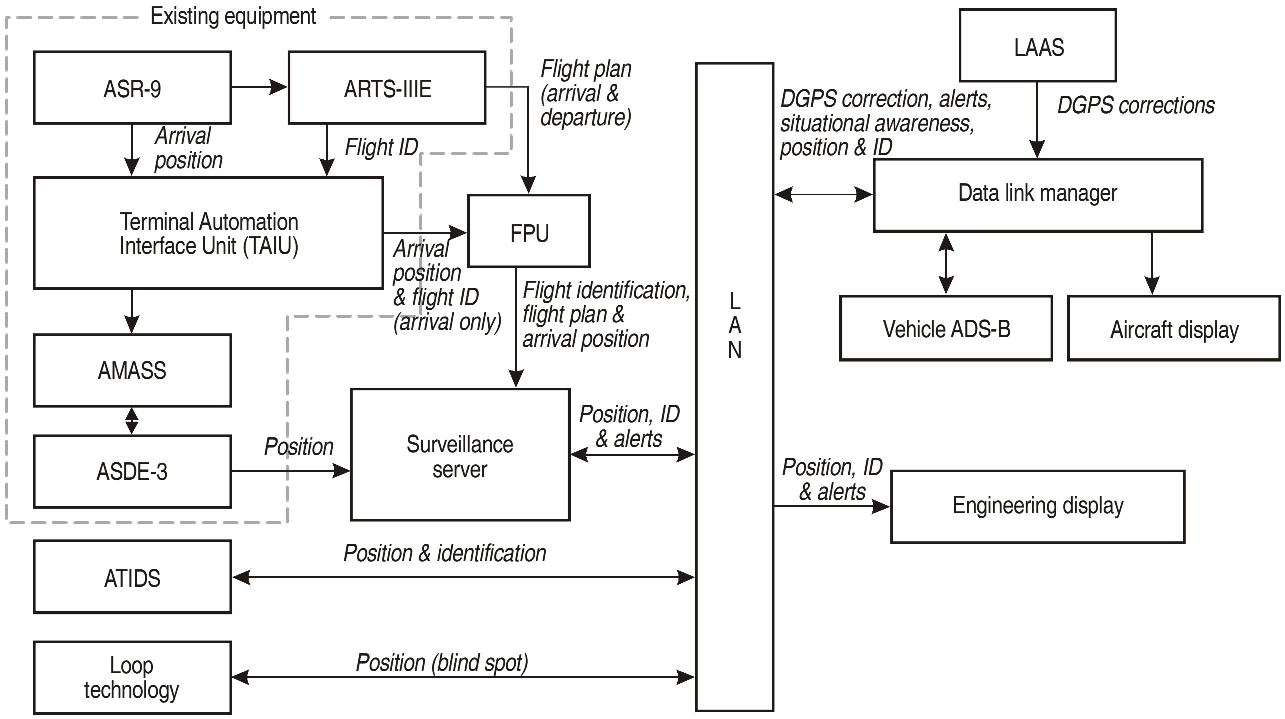

Figure E-4. RIRP system block diagram

one-second update rate and will provide the SSDS with raw digitized video. The raw video will be processed within the SSDS and position reports will be provided for fusion.

b) ASR-9: The ASR-9 is a terminal radar system that covers a 110 km (60 NM) range. The ASR-9 maintains an approximate five-second update rate. The RIRP system will utilize position data on arriving aircraft from the ASR-9.

c) Aerodrome target identification system (ATIDS): ATIDS is a multilateration system designed to track and provide identification of aircraft in the covered area of the aerodrome surface. This includes the complete surface movement area (taxiways and runways), plus 3 km arrival corridors up to 90 m (300 ft) above the surface. Mode S transponder-equipped aircraft are tracked using the “squitters” periodically transmitted from the aircraft. Transmissions are then received by receivers/transmitters located around the aerodrome. Time difference of arrival (TDOA) calculations are performed on the receptions to produce a position report. Additionally, ATIDS can receive ADS-B transmissions on the 1 090 MHz frequency to attain position and other information contained in the aircraft transmissions.

d) Loop technology: The RIRP system also utilizes loop technology in the loop sensor sub-system (LSS) to aid in the reduction of gaps in coverage. Inductive loops, similar to those used in automotive traffic systems (e.g. traffic light triggering), are placed in the taxiway. An aircraft or vehicle passing over a loop produces nose and tail detection that can be processed into position reports by the surveillance server.

e) Vehicle ADS-B: The vehicle ADS-B system utilizes ADS-B concepts to provide surveillance of aerodrome surface vehicles to controllers as well as to provide situational awareness to vehicle operators. Each equipped vehicle determines its own position utilizing D-GNSS technology and broadcasts the vehicle position and its identification to three base stations covering the aerodrome. A master base station that interfaces with the RIRP LAN via the data link manager gathers this position and identification information.

f) ARTS-IIIE: The ARTS-IIIE automation system provides flight plan information for arriving and departing aircraft.

g) Local area augmentation system (LAAS): A LAAS ground station provides D-GNSS corrections. These corrections will be available on the LAN through the data link manager for various systems to up-link them to aircraft and vehicles.

4.4 Outputs

The system also has the capability to provide situational awareness of aircraft and other targets from the SSDS, as well as runway hold bar information, to users, including the following:

a) Aircraft displays: Traffic and safety alerts can be up-linked, via the data link manager utilizing the vehicle ADS-B system, from the SSDS to developmental displays in aircraft. Figures E-5 and E-6 illustrate two moving map displays for use in aircraft or vehicles to indicate routing and conflict alert information.

b) Controller displays: The SSDS will provide a colour display for ATC. For each aircraft, the display will show an optimal position report and identification. Additionally, the display will show incursion alerts and holding position information.

c) Data link manager (DLM): The DLM serves as a gateway between the RIRP LAN and external systems. These systems include the vehicle ADS-B system, the LAAS ground station, and future data

Figure E-5. Cockpit arrival moving map display

Figure E-6. Cockpit departure moving map display

link communication projects. The DLM provides an interface for target reports to be exchanged between the vehicle ADS-B system and the RIRP LAN, as well as providing the safety alerts from the RIRP system to be up-linked to vehicles and aircraft.

d) Vehicle operator displays: As previously mentioned, the vehicle ADS-B system will provide position, identification and safety alert information to vehicle operators.

4.5 On-board guidance

4.5.1 The RIRP system trials included the ability of an aircraft (or vehicle) to perform and maintain a taxi route in visibility conditions of 75 m RVR or less.

4.5.2 In visibility condition 4, the operational and performance requirements for the surveillance, routing and control functions should account for the ability of an aircraft to self-navigate on the movement area. These functions may be wholly contained within the avionics or provided by data link from an aerodrome A-SMGCS.

4.5.3 Position estimation error values, as outlined in Table E-1, are based on an allocation of the total system errors relative to minimum aerodrome runway, taxiway and apron design requirements specified in Annex 14, Volume I.

4.5.4 The allocations are made to accommodate sufficient path steering errors for various aircraft types, and they are based on operational and simulator performance data.

4.5.5 The longitudinal position estimation errors assigned in Table E-1 are based on the assumption that the guidance sensor achieves the same level of performance in all horizontal directions.

4.5.6 As an example, Figure E-7 illustrates the key taxiway design standards for aerodrome reference code letter E, which gives a margin of 15.5 m between the wing tips and any objects, including the wings of aircraft on parallel taxiways. The minimum margin between the main wheels and taxiway edge is 4.5 m. The standards also recommend a shoulder of 10.5 m, thus yielding a margin of 15 m between the wheels and outer edge of the shoulder. The result is that the aircraft can deviate by 15 m from the taxiway centre line before there is risk of an incident, and therefore the containment limit is defined to be this value.

4.5.7 The containment limit of 15 m is applicable only to aerodromes of codes D and E. Since the margin is less for aerodromes of codes A, B and C, the containment limit for those cases is accordingly defined to be 8 m.

Table E-1. Lateral and longitudinal position estimation errors required for on-board guidance

Aerodrome code	*Lateral and longitudinal position estimation errors (95% in metres)*		
	Rapid exit, normal and apron taxiways	*Stand taxilane*	*Stand*
A	0.4	0.4	0.3
B	0.6	0.4	0.3
C	0.8	0.5	0.4
D	1.1	0.6	0.5
E	1.1	0.6	0.5

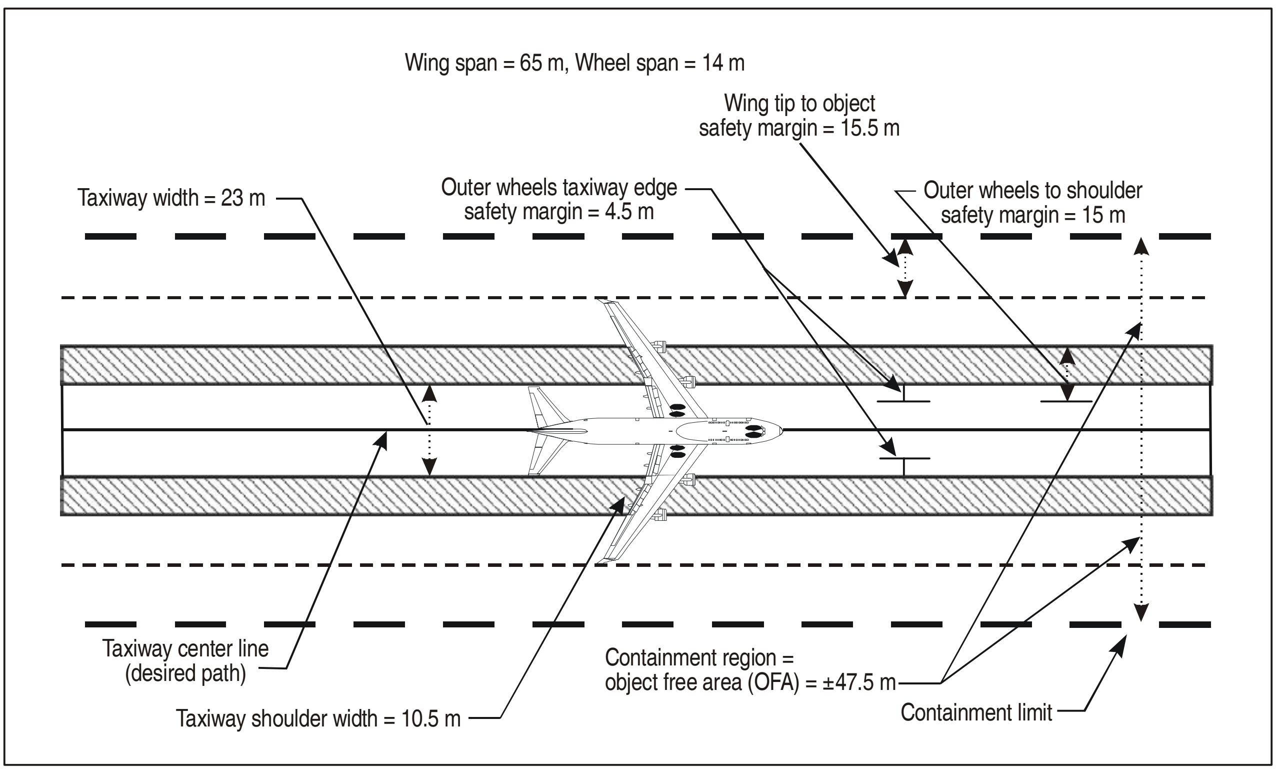

Figure E-7. Taxiway design standards for aerodrome code letter E aircraft

— END —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

6/04, E/P1/1640

Order No. 9830
Printed in ICAO

ISBN 92-9194-305-3