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EUROCONTROL Specification for Minimum Safe Altitude Warning

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Abstract

This document specifies the minimum requirements for the development, configuration and use of Minimum Safe Altitude Warning (MSAW) in the ECAC area.

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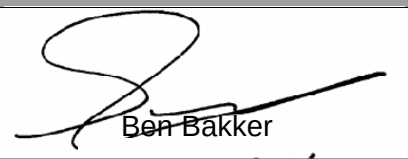
Technical Manager	 Ben Bakker	19-5-2009
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CONTENTS

1. INTRODUCTION

This document is aimed at all Air Navigation Service Providers (ANSPs) in the European Civil Aviation Conference (ECAC) area. It specifies the minimum requirements for the development, configuration and use of Minimum Safe Altitude Warning (MSAW). MSAW is a ground-based safety net intended to warn the controller about increased risk of controlled flight into terrain accidents by generating, in a timely manner, an alert of aircraft proximity to terrain or obstacles.

This document does not apply to Approach Path Monitoring (APM) which is a separate safety net. Minimum requirements for APM are specified in a separate document.

The European Convergence and Implementation Plan (ECIP) contains an Objective (ATC02.6) for ECAC-wide standardisation of MSAW in accordance with the EUROCONTROL Specification for Minimum Safe Altitude Warning (this document). This document specifies, in qualitative terms, the common performance characteristics of MSAW as well as the prerequisites for achieving these performance characteristics.

It should also be noted that Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation) contains *inter alia* the following essential requirements:

- "*Systems and operations of the EATMN shall achieve agreed high levels of safety. Agreed safety management and reporting methodologies shall be established to achieve this.*"
- "*In respect of appropriate ground-based systems, or parts thereof, these high levels of safety shall be enhanced by safety nets which shall be subject to agreed common performance characteristics.*"

The present document facilitates harmonization of the MSAW elements of the ground based safety nets and sets up the prerequisites for the refinement, in quantitative terms, of the common performance characteristics which might be developed in a further step in response to the requirements of the SES interoperability Regulation.

This document is targeted at stakeholders identified in ECIP ATC02.6, and the requirements are placed on ANSPs. The document is structured as follows:

- Chapter 1 describes the purpose, scope and structure of the document.
- Chapter 2 lists reference documents, explains terms and contains a list of abbreviations.

- Chapter 3 describes the MSAW concept of operations. It provides the contextual information for interpretation of the requirements contained in Chapter 4.
- Chapter 4 specifies the minimum qualitative requirements that are regarded as necessary for effective MSAW. It does not prescribe implementation aspects. Only the ***minimum*** requirements that are considered essential for ensuring the effectiveness of MSAW in the ECAC area are specified. These requirements are necessarily of a qualitative nature considering the implications of local factors that need to be considered. The requirements in this chapter are normative in the sense that:
  - Requirements using the operative verb ***"shall"*** are mandatory to claim compliance with the Specification. Mandatory requirements are explicitly numbered with the prefix "MSAW-".
  - Requirements using the operative verb ***"should"*** are recommended.
  - Requirements using the operative verb ***"may"*** are optional.
  - Requirements using the operative verb ***"will"*** denote a statement of intent.
- Chapter 5 identifies the comprehensive guidance material available to assist in implementing this Specification.

Use of the word "shall" is avoided in Chapter 3 of this Specification and in the guidance material in order to emphasise the introductory and explanatory rather than normative nature of the information provided.

Some of the terms in paragraph 2.2 and the requirements on procedures in paragraph 4.2 are derived from paragraph 15.7.4 of ICAO Doc 4444. Any differences in formulation are intended to remove ambiguity and not to imply deviation from ICAO provisions. For example, no references to "minimum safe altitude" are included in this Specification. ICAO uses this term but does not provide a definition. Use of the term in this Specification could introduce ambiguity regarding the purpose of MSAW: the sole purpose of MSAW is to enhance safety and not to monitor adherence to legal minima.

2. CONVENTIONS REGARDING TERMS

2.1 Reference Documents

[EURO-HRS]	Guidelines for Trust in Future ATM Systems: Principles, HRS/HSP-005-GUI-03, Edition 1.0, May 2003
[SRC-ESARR4]	ESARR 4: Risk Assessment and Mitigation in ATM, Edition 1.0, 05-04-2001

2.2 Explanation of Terms

alert	Indication of an actual or potential hazardous situation that requires particular attention or action.
altitude	The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).
ATS surveillance service	Term used to indicate a service provided directly by means of an ATS surveillance system.
elevation	The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.
false alert	Alert which does not correspond to a situation requiring particular attention or action (e.g. caused by split tracks and radar reflections).

flight level	A surface of constant atmospheric pressure which is related to a specific pressure datum, 1 013.2 hecto-pascals (hPa), and is separated from other such surfaces by specific pressure intervals. *Note 1.– A pressure type altimeter calibrated in accordance with the Standard Atmosphere:* *a. when set to a QNH altimeter setting, will indicate altitude;* *b. when set QFE altimeter setting, will indicate height above the QFE reference datum;* *c. when set to a pressure of 1 013.2 hPa, may be used to indicate flight levels.* *Note 2.– The terms "height" and "altitude", used in Note 1 above, indicate altimetric rather than geometric heights and altitude.*
ground-based safety net	A ground-based safety net is functionality within the ATM system that is assigned by the ANSP with the sole purpose of monitoring the environment of operations in order to provide timely alerts of an increased risk to flight safety which may include resolution advice.
height	The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.
human performance	Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.
level	A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level.
minimum safe altitude warning	A ground-based safety net intended to warn the controller about increased risk of controlled flight into terrain accidents by generating, in a timely manner, an alert of aircraft proximity to terrain or obstacles.
nuisance alert	Alert which is correctly generated according to the rule set but is considered operationally inappropriate.

warning time	The amount of time between the first indication of an alert to the controller and the predicted hazardous situation. *Note.– The achieved warning time depends on the geometry of the situation.* *Note.– The maximum warning time may be constrained in order to keep the number of nuisance alerts below an acceptable threshold.*

2.3 Abbreviations and Acronyms

ADS	Automatic Dependent Surveillance
AGDL	Air-Ground Data Link
ANSP	Air Navigation Service Provider
APM	Approach Path Monitor
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATS	Air Traffic Service
EATMN	European Air Traffic Management Network
EC	European Commission
ECAC	European Civil Aviation Conference
ECIP	European Convergence and Implementation Plan
(E)GPWS	(Enhanced) Ground Proximity Warning System
ESARR	EUROCONTROL Safety Regulatory Requirement
FUA	Flexible Use of Airspace
GAT	General Air Traffic
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
MSAW	Minimum Safe Altitude Warning *Note.– Not to be confused with MSA (Minimum Sector Altitude).*
MSL	Mean Sea Level
OAT	Operational Air Traffic
QFE	Atmospheric pressure at aerodrome elevation *(or at runway threshold)*
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
SES	Single European Sky

SRC	Safety Regulatory Commission
VFR	Visual Flight Rules

3. MSAW CONCEPT OF OPERATIONS

3.1 Purpose of MSAW

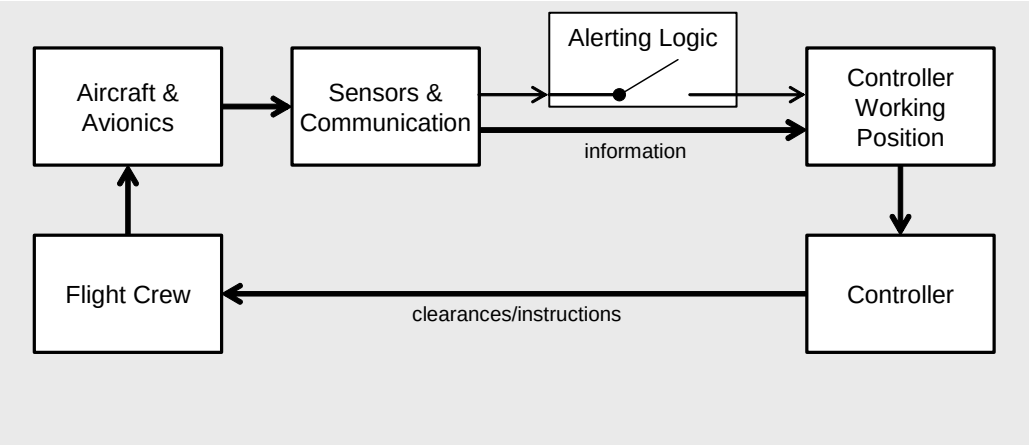

Fig. 1: Simplified ATC Control Loop

As illustrated in Fig. 1, today's ATC system is human centred; based on processing of a continuous stream of information, the controller issues clearances and instructions to prevent or resolve conflicts.

However, the drive for consistency in cognitive information processing tasks leads to selective perception/exposure, selective attention and selective interpretation. As a result, conflicts and deviations from clearances or instructions leading to an unsafe aircraft altitude can remain unnoticed.

MSAW adds independent alerting logic to the control loop in order to avoid controlled flight into terrain accidents by generating alerts of existing or pending situations, related to aircraft proximity to terrain or obstacles, which require attention/action.

MSAW is intended to function in the short term, if applicable providing warning times of up to 2 minutes.

3.2 Operational Context

When MSAW was first introduced, ATS surveillance services were in most cases provided using mixed (raw radar data supplemented with computer-generated synthetic data) situation displays. In the meantime, the norm for provision of ATS surveillance services has become full-synthetic situation displays in most ECAC States. Decision support tools are gradually being introduced to enable the controller to handle more traffic in order to cope with the ever increasing demand. At the same time, automated support systems have become more robust and trustworthy but also more complex and

interdependent. These changes imply a different operational context for MSAW.

It is essential that individual ANSPs establish a clear MSAW policy for their particular operational context to avoid ambiguity about the role and use of MSAW using the following generic policy statements as a starting point:

MSAW IS A GROUND-BASED SAFETY NET; ITS SOLE PURPOSE IS TO ENHANCE SAFETY AND ITS PRESENCE IS IGNORED WHEN CALCULATING SECTOR CAPACITY.

MSAW IS DESIGNED, CONFIGURED AND USED TO MAKE A SIGNIFICANT POSITIVE CONTRIBUTION TO AVOIDANCE OF CONTROLLED FLIGHT INTO TERRAIN ACCIDENTS BY GENERATING, IN A TIMELY MANNER, AN ALERT OF AIRCRAFT PROXIMITY TO TERRAIN OR OBSTACLES.

MSAW is only effective if the number of nuisance alerts remains below an acceptable threshold according to local requirements and if it provides sufficient warning time to resolve hazardous situations, governed by the inherent characteristics of the human centred system.

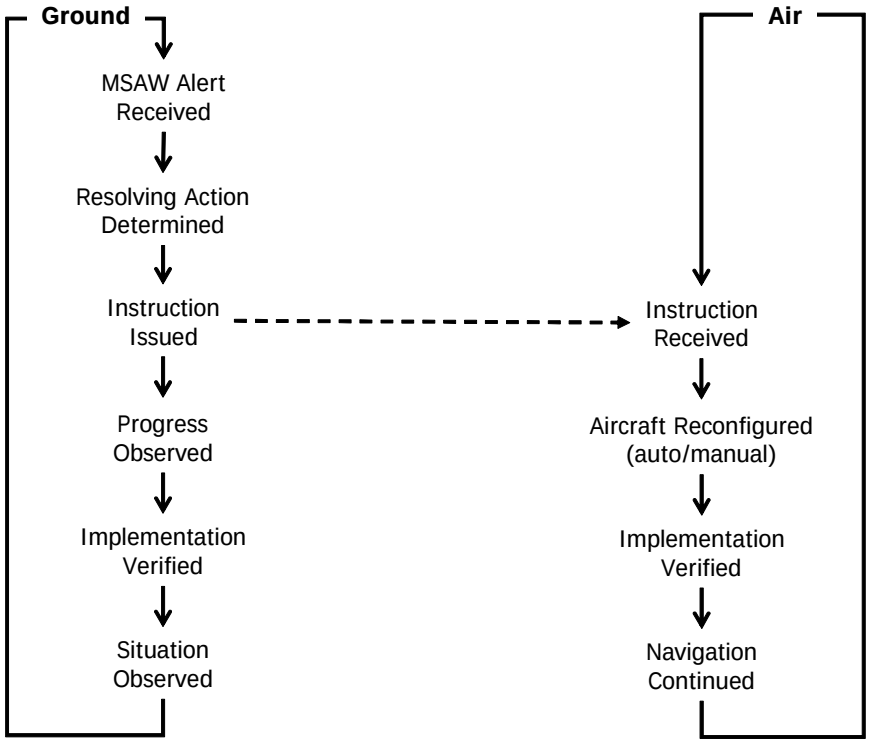

Fig. 2: Expanded ATC Control Loop (triggered by MSAW)

Fig. 2 illustrates the nominal sequence of events to resolve a particular situation as two loosely coupled loops. Being a human centred system, the Ground loop reflects the states of the controller and the Air loop reflects the states of the flight crew. For each state transition to occur certain preconditions have to be met and actions performed, complicated by many fixed or variable delays and anomalous cases.

3.3 Operational Concept

3.3.1 Human Performance Considerations

In order to be able to process all available information, the controller must acquire situational awareness and build a mental model of the airspace and traffic pattern. To control the situation and make decisions, the controller has to establish strategies and tactics to handle the traffic flows and conflicts.

Hazardous situations related to aircraft altitude can remain unnoticed by the flight crew and the controller. The controller's workload and priorities may cause an imminent hazardous situation to remain undetected if not alerted by MSAW.

The use of MSAW will depend on the controller's trust. Trust is a result of many factors such as reliability and transparency. Neither mistrust nor complacency is desirable; training and experience is needed to develop trust at the appropriate level (see [EURO-HRS]).

For MSAW to be effective, the controller must have a positive attitude towards MSAW. This requires that the following aspects are addressed:

- **Appropriateness and timeliness**
  The rule set for generating alerts should be appropriate; dissonance with normal control practices should be avoided.
- **Effectiveness**
  The controller in charge may not notice or recognise the reason for an alert for the same reasons that left the potentially hazardous situation undetected. This should be addressed in HMI design.
- **Comprehensibility and performance monitoring**
  The increasing complexity of MSAW and the environment in which it is used should be addressed through appropriate training and competency assessment. Practices and controller perception of the effectiveness of MSAW should be evaluated periodically and following changes to MSAW. Lessons from particular situations or incidents in which MSAW was involved should be shared through appropriate mechanisms.

3.3.2 Design Considerations

MSAW should perform in concert with the airspace design and classification, variety of airspace users, Flexible Use of Airspace (FUA) and the applicable procedures for air navigation services.

Special consideration should be given to making all ground-based safety nets and controller tools perform in concert.

Dependent on the diversity of these aspects, MSAW should be capable of using different parameters for generation of alerts. Different parameters may

be applied in the case of system degradation (e.g. unavailability of one or more radar stations).

Local instructions concerning the use of MSAW should be established to ensure that MSAW is used in a safe and effective manner. Pertinent data should be regularly analysed in order to monitor and optimise the performance of MSAW.

3.3.3 Technical Aspects

MSAW is suitable for use in any airspace covered by adequate surveillance.

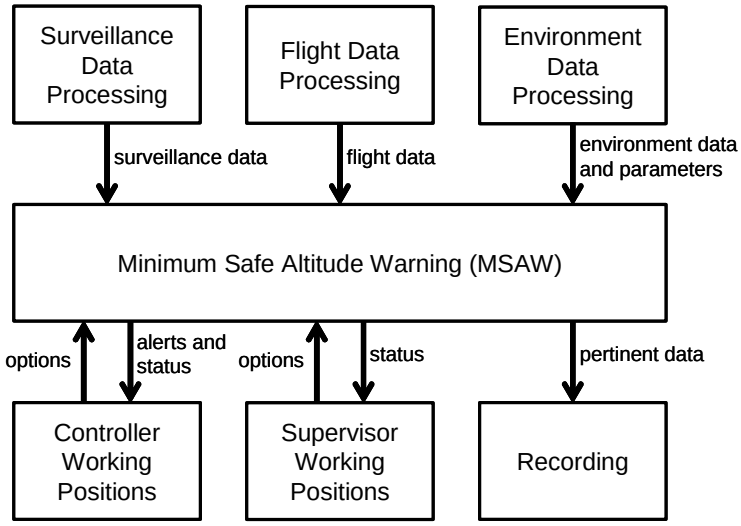

Fig. 3: MSAW Context Diagram

As illustrated in Fig. 3, MSAW should obtain information from Surveillance Data Processing, from Environment Data Processing and possibly from Flight Data Processing in order to generate alerts:

- Surveillance data including tracked pressure altitude information should be used to predict hazardous situations
- Flight data should be used as follows:
  - Type/category of flight: to determine the eligibility for alert generation and possibly also the parameters applied
  - Concerned sector(s): to address alerts
  - Cleared Flight levels: to increase the relevance of alert generation
- Environment data and parameters should include:
  - Terrain and obstacle data
  - Alerting parameters
  - Additional items (QNH, temperature, etc.)

Alerts should be presented at least at a Controller Working Position of the control sector working the aircraft. Status information regarding the technical availability of MSAW is to be provided to all Working Positions. Selectable options of MSAW related to eligibility, configuration and technical availability may be available at Controller and Supervisor Working Positions.

All pertinent data for offline analysis of MSAW should be recorded.

3.4 Safety Aspects

It is assumed that EUROCONTROL Safety Regulatory Requirements are effectively implemented. It is recommended to put emphasis on [SRC-ESARR4] and its guidance material for the implementation of, and changes to, MSAW applications.

3.5 Future Directions and Need for Change

MSAW will have to meet future demands imposed by, amongst other things, further traffic increase, changing traffic patterns, FUA, changing aircraft characteristics, further automation in the air and on the ground and, potentially, the introduction of new concepts.

The compatibility of MSAW and other ground-based and airborne safety nets, in particular (E)GPWS, needs to be maximised.

Availability of improved or new aircraft information through Mode S, ADS and AGDL will offer new opportunities to improve MSAW.

This could amongst others lead to changes in the following aspects of MSAW:

- Correlation of ATC constraints with aircraft intent in order to further reduce the number of nuisance alerts;
- Increased look ahead time and multi-level or different types of alerts;
- Correlation of alerts from multiple sources (on the ground and in the air) to generate combined alerts.

4. SPECIFIC REQUIREMENTS

4.1 Policy, Organisational Clarity and Training Requirements

4.1.1 Policy

MSAW-01 The ANSP ***shall*** have a formal policy on the use of MSAW consistent with the operational concept and safety management system applied to avoid ambiguity about the role and purpose of MSAW.

The policy ***should*** be consistent with the generic policy statements in section 3.2 of this Specification but may contain more detail or additional aspects called for by local factors.

The policy ***should*** be communicated to all relevant staff in order to ensure consistency of all design, configuration, operational use and monitoring activities in compliance with the intended use of MSAW.

4.1.2 Responsibility for Management of MSAW

MSAW-02 The ANSP ***shall*** assign to one or more staff, as appropriate, the responsibility for overall management of MSAW.

It ***should*** be possible for other staff in the organisation to identify the assigned staff. The assigned staff ***should*** seek advice from the MSAW manufacturer, as appropriate.

4.1.3 Training and Competence

MSAW-03 The ANSP ***shall*** ensure that all controllers concerned are given specific MSAW training and are assessed as competent for the use of the relevant MSAW system.

Note.– The primary goal of the training is to develop and maintain an appropriate level of trust in MSAW, i.e. to make controllers aware of the likely situations where MSAW will be effective and, more importantly, situations in which MSAW will not be so effective (e.g. sudden, unexpected manoeuvres).

4.2 Requirements on Procedures

4.2.1 Local Instructions

MSAW-04 Local instructions concerning use of MSAW ***shall*** specify, *inter alia*:

a) the types of flight (GAT/OAT, IFR/VFR, etc.) which are eligible for generation of alerts;

b) the volumes of airspace within which MSAW is implemented;

c) the method of displaying the MSAW to the controller;

d) in general terms, the parameters for generation of alerts as well as alert warning time;

e) the volumes of airspace within which MSAW can be selectively inhibited and the conditions under which this will be permitted as well as applicable procedures;

f) conditions under which MSAW alerts may be inhibited for individual flights as well as applicable procedures.

4.2.2 Controller Actions

MSAW-05 In the event an alert is generated in respect of a controlled flight, the controller ***shall*** without delay assess the situation and if necessary the flight ***shall*** be given appropriate instructions to avoid terrain.

4.2.3 MSAW Performance Analyses

MSAW-06 MSAW performance ***shall*** be analysed regularly to identify possible shortcomings related to MSAW.

4.2.4 Statistical Analyses

The appropriate ATS authority ***should*** retain electronic records of all alerts generated. The data and circumstances pertaining to each alert ***should*** be analysed to determine whether an alert was justified or not. Non-justified alerts, e.g. during visual approach, ***should*** be ignored. A statistical analysis ***should*** be made of justified alerts in order to identify possible shortcomings in airspace design and ATC procedures as well as to monitor overall safety levels.

4.3 Requirements on MSAW Capabilities

4.3.1 Alerting Performance

MSAW-07 MSAW ***shall*** detect operationally relevant situations for eligible aircraft.

MSAW-08 MSAW ***shall*** alert operationally relevant situations for eligible aircraft.

Note.– Situations are operationally relevant when covered by the adopted rule set and optimisation strategy. The rule set and optimisation strategy should be determined taking into account the relevant local factors. MSAW should not be expected to alert all operationally relevant situations.

MSAW-09 MSAW alerts ***shall*** attract the controller's attention and identify the aircraft involved in the situation; MSAW alerts ***shall*** be at least visual.

An audible element ***should*** be included to improve the systems ability to draw the controller's attention to the alert as appropriate (e.g. in Control Towers). If a continuous audible element is included, an acknowledgement mechanism ***may*** be provided to silence an alert.

MSAW-10 The number of nuisance alerts produced by MSAW ***shall*** be kept to an effective minimum.

Note.– Human factors and local circumstances determine what constitutes an effective minimum.

MSAW-11 The number of false alerts produced by MSAW ***shall*** be kept to an effective minimum.

Note.– Local circumstances determine what constitutes an effective minimum.

4.3.2 Warning Time

MSAW-12 When the geometry of the situation permits, the warning time ***shall*** be sufficient for all necessary steps to be taken from the controller recognising the alert to the aircraft successfully executing an appropriate manoeuvre.

Note.– Insufficient warning time may be provided in cases of sudden, unexpected manoeuvres.

MSAW-13 MSAW ***shall*** continue to provide alert(s) as long as the alert conditions exist.

4.3.3 Alert Inhibition

MSAW-14 MSAW ***shall*** provide the possibility to inhibit alerts for predefined volumes of airspace and for individual flights.

Note.– It may be necessary to inhibit alerts for predefined volumes of airspace (e.g. exercise areas) to suppress unnecessary alerts. It may be necessary to inhibit alerts for specific flights (e.g. Calibration Service Aircraft on a defined flight pattern) to suppress unnecessary alerts.

MSAW-15 Alert inhibitions ***shall*** be made known to all controllers concerned.

4.3.4 Status Information

MSAW-16 Status information ***shall*** be presented to supervisor and controller working positions in case MSAW is not available.

4.3.5 Adaptability

MSAW ***should*** be adaptable for the procedures in use in all distinct volumes of airspace.

MSAW ***may*** need to take into account the type of flight as well as the specific volume of airspace in which the aircraft is flying, in order to apply appropriate parameters or trajectory estimation. Different parameters ***may*** be applied in the case of system degradation (e.g. unavailability of one or more radar stations).

4.3.6 Data Recording

MSAW-17 All pertinent MSAW data ***shall*** be made available for off-line analysis.

Note.– Off-line analysis may need access to other data sources as well (surveillance data and voice recordings) for complete analysis.

5. GUIDANCE MATERIAL

5.1 Structure of the Guidance Material

Comprehensive guidance material to assist in implementing this specification covers the full MSAW lifecycle:

- Definition of objectives
- Implementation or change
- Tuning and validation
- Operating and monitoring

The guidance material consists of a document titled **EUROCONTROL Guidance Material for Minimum Safe Altitude Warning** with several appendices. Most appendices can be used as stand-alone documents for particular purposes. Table 1 shows the structure of the guidance material.

Title	**Purpose**
EUROCONTROL Guidance Material for Minimum Safe Altitude Warning	General description of the full MSAW lifecycle, aimed at staff with responsibility for overall management of MSAW.
Appendix A: Reference MSAW System	Detailed technical explanation of typical implementation details of MSAW with emphasis on parameterisation and performance optimisation. Optimisation concepts are also covered in detail.
Appendix B: Safety Assurance	A set of three documents that can be used as starting point for MSAW safety assurance work in a particular local context.
Appendix B-1: Initial Safety Argument for MSAW System	ANSPs may find it convenient to present the safety argument as a stand-alone document initially, as is the case with this document. However, the argument will ultimately become part of the safety case document and the stand-alone version will then become defunct.
Appendix B-2: Generic Safety Plan for MSAW Implementation	Describes what safety assurance activities should be considered at each lifecycle phase, who should do them, and what the criteria for success are.

Appendix B-3: Outline Safety Case for MSAW System	Addresses in detail the assurance and evidence from the System Definition stage and outlines the likely assurance and evidence for the later stages.
Appendix C: Cost Framework for the Standardisation of MSAW	Assists in identifying potential financial implications of standardisation of MSAW in compliance with the EUROCONTROL Specification for Minimum Safe Altitude Warning.
Appendix D: Case Study	A set of two documents describing the (partial) application of the optimisation and safety assurance guidance material in a demanding environment.
Appendix D-1: Enhancement of MSAW for Skyguide	Identifies potential solutions for extending MSAW coverage throughout Skyguide's Area of Responsibility.
Appendix D-2: Functional Hazard Assessment of MSAW for Skyguide	Describes the Functional Hazard Assessment of the identified potential solutions for extending MSAW, performed as an initial step of safety assurance activities.

Table 1: Structure of the guidance material

5.2 Availability and Feedback

The guidance material is freely available at www.eurocontrol.int/safety-nets and regularly updated based on feedback received.

Feedback and questions can be addressed to the contact listed in each document and to safety-nets@eurocontrol.int .

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