

EUROCONTROL Guidelines for Minimum Safe Altitude Warning - Part II

Lifecycle Description

Edition: 1.0

Edition Date: 18/01/2017

Reference nr: EUROCONTROL-GUID-160

EUROCONTROL Guidelines for Minimum Safe Altitude Warning

Part II - Lifecycle Description

DOCUMENT IDENTIFIER : EUROCONTROL-GUID-160

Edition Number	:	1.0
Edition Date	:	18/01/2017
Status	:	Released Issue
Intended for	:	General Public
Category	:	EUROCONTROL Guidelines

DOCUMENT CHARACTERISTICS

TITLE			
EUROCONTROL Guidelines for Minimum Safe Altitude Warning Part II - Lifecycle Description			
	Publications Reference: GUID-160		
	ISBN Number: 978-2-87497-082-5		
Document Identifier EUROCONTROL-GUID-160	Edition Number: 1.0		
	Edition Date: 18/01/2017		
Abstract			
<p>These Guidelines specify the minimum requirements and provide comprehensive guidance for the definition, implementation, optimisation and operation of Minimum Safe Altitude Warning (MSAW). Part I describes the MSAW concept of operations as well as the specific requirements on MSAW. Part II, this document, contains overall guidance for the complete lifecycle of MSAW. Part III specifies a generic example of an MSAW implementation as well as detailed technical guidance for optimisation of MSAW.</p>			
Keywords			
Safety Nets MSAW			
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STATUS, AUDIENCE AND ACCESSIBILITY				
Status	Intended for		Accessible via	
Working Draft	<input type="checkbox"/>	General Public	<input checked="" type="checkbox"/>	Intranet <input type="checkbox"/>
Draft	<input type="checkbox"/>	EUROCONTROL	<input type="checkbox"/>	Extranet <input type="checkbox"/>
Proposed Issue	<input type="checkbox"/>	Restricted	<input type="checkbox"/>	Internet (www.eurocontrol.int) <input checked="" type="checkbox"/>
Released Issue	<input checked="" type="checkbox"/>			

DOCUMENT APPROVAL

See Part I – Concept and Requirements

DOCUMENT CHANGE RECORD

See Part I – Concept and Requirements

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EXECUTIVE SUMMARY

These Guidelines specify the minimum requirements and provide comprehensive guidance for the definition, implementation, optimisation and operation of Minimum Safe Altitude Warning (MSAW).

Ground-based safety nets are functionalities within the ATM system with the sole purpose of monitoring the environment of operations in order to provide timely alerts of an increased risk to flight safety.

MSAW is a ground-based safety net that warns 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.

The main objective of these Guidelines is to support ANSPs in the definition, implementation, optimisation and operation of MSAW by means of:

- Part I describing the MSAW concept of operations as well as the specific requirements on MSAW
- Part II, **this document**, containing overall guidance for the complete lifecycle of MSAW
- Part III specifying a generic example of an MSAW implementation and providing detailed guidance for optimisation and testing of MSAW

Together with similar Guidelines for Short Term Conflict Alert (STCA), Approach Path Monitor (APM) and Area Proximity Warning (APW) these Guidelines provide “Level 3” documentation for evolutionary improvement of ground-based safety nets, i.e.:

- “Level 1” – documented in the EUROCONTROL Operational Requirement Document for EATCHIP Phase III ATM Added Functions (Volume 2), published in 1998 with emphasis on automation
- “Level 2” – documented in EUROCONTROL Specifications and Guidance Material for STCA, MSAW, APM and APW, published in 2007-2008 providing a broader context than automation alone, e.g. pointing out the importance of policy, organisational clarity and training
- “Level 3” – documented in EUROCONTROL Guidelines for STCA, MSAW, APM and APW, published in 2017 incorporating the results of SESAR I as well as lessons learned

1. Introduction

1.1 Purpose of this document

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.

Part I of the EUROCONTROL Guidelines for MSAW contains specific requirements, a number of which must be addressed at an organisational or managerial level and others, more system capability related, which need to be addressed with significant input from operational, technical and safety experts.

The purpose of Part II of the EUROCONTROL Guidelines for MSAW is to provide practical guidance to assist in implementing the specific requirements. The guidance covers the full MSAW lifecycle.

1.2 Structure of this document

Chapter 1 describes the purpose and structure of this document.

Chapter 2 contains a general introduction and overview of the MSAW lifecycle, including defining, implementing, optimising and operating MSAW.

Chapter 3 elaborates organisational issues regarding MSAW, including definition of roles and responsibilities, definition of operational requirements, and development of a policy and a safety case.

Chapter 4 contains a guide to MSAW procurement and improvement.

Chapter 5 addresses MSAW tuning and validation aspects.

Chapter 6 highlights MSAW management and training aspects.

1.3 Reference documents

[Doc 4444]	ICAO Doc 4444: Procedures for Air Navigation Services - Air Traffic Management
[SRC-ESARR4]	ESARR 4: Risk Assessment and Mitigation in ATM, Edition 1.0, 05-04-2001
[SRC28.06]	SRC Policy on Ground Based Safety Nets – Action Paper submitted by the Safety Regulation Commission Co-ordination Group (SRC CG) – 15/03/07

1.4 Explanation of terms

This section provides the explanation of terms required for a correct understanding of the present document. Most of the following explanations are drawn from [Doc 4444] and [SRC28.06] as indicated.

alert	Indication of an actual or potential hazardous situation that requires particular attention or action.
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altitude [Doc 4444]	The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).
approach path monitor	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 an unsafe aircraft flight path during final approach.
area proximity warning	A ground-based safety net intended to warn the controller about unauthorised penetration of an airspace volume by generating, in a timely manner, an alert of a potential or actual infringement of the required spacing to that airspace volume.
ATS surveillance service [Doc 4444]	Term used to indicate a service provided directly by means of an ATS surveillance system.
elevation [Doc 4444]	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 [Doc 4444]	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.
<p>Note 1: A pressure type altimeter calibrated in accordance with the Standard Atmosphere:</p> <ol style="list-style-type: none"> when set to a QNH altimeter setting, will indicate altitude; when set QFE altimeter setting, will indicate height above the QFE reference datum; when set to a pressure of 1 013.2 hPa, may be used to indicate flight levels. 	
<p>Note 2: The terms "height" and "altitude", used in Note 1 above, indicate altimetric rather than geometric heights and altitude.</p>	
ground-based safety net [SRC28.06]	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 [Doc 4444]	The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.
human performance [Doc 4444]	Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.
level [Doc 4444]	A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level.
nuisance alert	Alert which is correctly generated according to the rule set but is considered operationally inappropriate.

minimum safe altitude warning [derived from Doc 4444]	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.
short term conflict alert [derived from Doc 4444]	A ground-based safety net intended to assist the controller in preventing collision between aircraft by generating, in a timely manner, an alert of a potential or actual infringement of separation minima.
warning time	<p>The amount of time between the first indication of an alert to the controller and the predicted hazardous situation.</p> <p>Note 1: The achieved warning time depends on the geometry of the situation.</p> <p>Note 2: The maximum warning time may be constrained in order to keep the number of nuisance alerts below an acceptable threshold.</p>

1.5 Abbreviations and acronyms

ADS	Automatic Dependent Surveillance
AGDL	Air-Ground Data Link
ANSP	Air Navigation Service Provider
APM	Approach Path Monitor
APW	Area Proximity Warning
ASM	Airspace Management
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATM	Air Traffic Management
ATS	Air Traffic Service
CFIT	Controlled Flight Into Terrain
CFL	Cleared Flight Level
CPU	Central Processing Unit
DTED	Digital Terrain Elevation Data
EATCHIP	European ATC Harmonisation and Integration Programme
EATMN	European Air Traffic Management Network
EC	European Commission
ESARR	EUROCONTROL Safety Regulatory Requirement
ESSIP	European Single Sky Implementation
FAT	Factory Acceptance Test
FDPS	Flight Data Processing System
FUA	Flexible Use of Airspace
GAT	General Air Traffic

HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ISA	International Standard Atmosphere
MOCA	Minimum Obstacle Clearance Altitude
MSAW	Minimum Safe Altitude Warning Note: Not to be confused with MSA (Minimum Sector Altitude)
MRVA	Minimum Radar Vectoring Altitude
MSA	Minimum Sector Altitude
MSL	Mean Sea Level
OAT	Operational Air Traffic
PoR	Point of Risk
QFE	Atmospheric pressure at aerodrome elevation (<i>or at runway threshold</i>)
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RVSM	Reduced Vertical Separation Minima
SAT	Site Acceptance Test
SES	Single European Sky
SESAR	Single European Sky ATM Research
SFL	Selected Flight Level
SID	Standard Instrument Departure
SRC	Safety Regulation Commission
SSR	Secondary Surveillance Radar
STAR	Standard Arrival Route
STCA	Short Time Conflict Alert
TOV	Time Of Violation
VFR	Visual Flight Rules

2. The MSAW lifecycle

2.1 Overview of the MSAW lifecycle

The MSAW lifecycle represents an ideal process followed by ANSPs to ensure a solid and consistent development of MSAW from the initial procurement to and during the operational use.

Figure 1 is a concise representation of the whole lifecycle. Each phase is covered by appropriate guidance in the document.

2.1.1 Defining MSAW

The initial step of the lifecycle is the definition of roles and responsibilities inside the organisation, to establish who has the responsibility for the management of MSAW. Roles are made clear and well known inside the organisation to ensure a consistent development of the system (section 3.1).

Then, the core issue is the definition of the operational requirements of MSAW, based on a careful consideration of the local needs and constraints of the operational context in which the MSAW is being introduced (section 3.4). Two other strictly interrelated processes are: the consideration of examples (section 3.3) and the development of a policy and safety case (section 3.4.5).

In performing the whole phase, representatives from different kinds of roles in the organisation should be involved: operational, technical and safety experts.

2.1.2 Implementing MSAW

The previous steps are all needed to take an appropriate decision about the MSAW procurement, either when the product is purchased from an external manufacturer (section 4.2) or when MSAW is enhanced (section 4.3).

This phase is mostly performed by engineers and technical experts.

System verification (section 4.6) is performed either when implementing a new MSAW from scratch or when enhancing an existing MSAW.

Based on a verification methodology, an appropriate feedback loop ensures that the phase is not terminated if the MSAW is not functioning according to the technical specifications previously established.

2.1.3 Optimising MSAW

The third phase is aimed at optimising the system in order to meet the operational requirements identified in the first phase. It also addresses validating the system before making it fully operational. The most essential steps are MSAW tuning and validation (chapter 5).

This phase relies on close collaboration between technical staff and operational experts.

Based on acceptance tests with controllers and/or on the use of optimisation tools, an appropriate feedback loop ensures that the phase is not terminated if the MSAW does not meet the established operational requirements.

2.1.4 Operating MSAW

When MSAW is deemed validated or optimised, adequate training is provided to both ATCOs (section 6.2) and engineers (section 6.3).

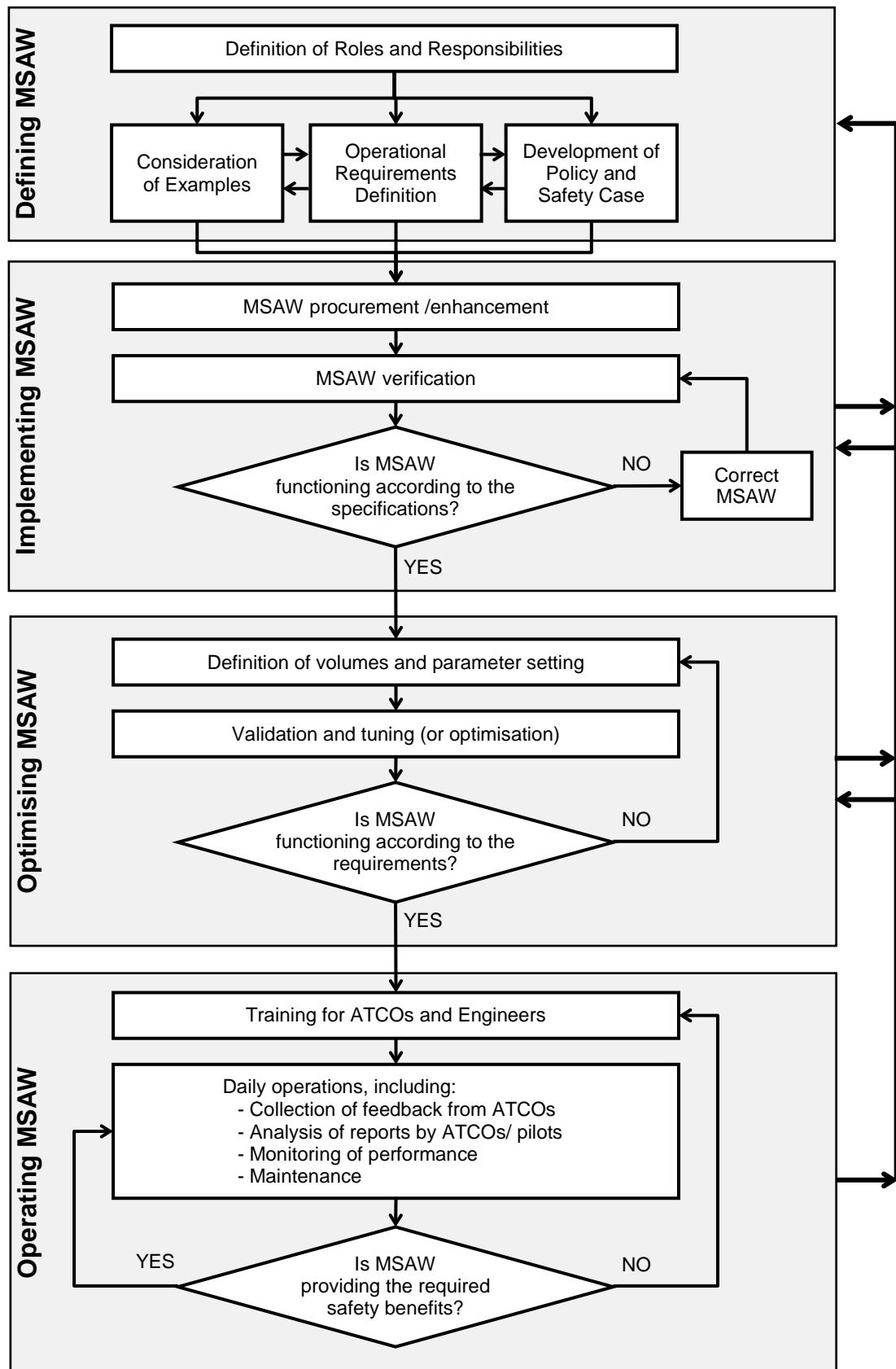
- Once MSAW is fully operational, a set of parallel processes are put in place:
- Collection of feedback from ATCOs
- Analysis of Pilots/ATCOs reports (section 6.4)

- Monitoring of MSAW performance (section 6.5)
- Maintenance (section 6.6)

Also this phase requires a close collaboration between operational and technical staff. Safety experts should also be involved, to ensure that the MSAW role is adequately considered in evaluating the whole safety performance of the ANSP.

Based on the parallel processes described above, an appropriate feedback loop ensures reverting to a tuning process, every time MSAW is not providing the required safety benefits.

It is to be noted that the whole MSAW lifecycle is not a linear process, due to the ever-changing nature of the operational context in which MSAW is embedded. Thus iterations are still possible not only within each phase, but also between the different phases.

**Figure 1: The MSAW lifecycle**

3. Defining MSAW

3.1 Introduction

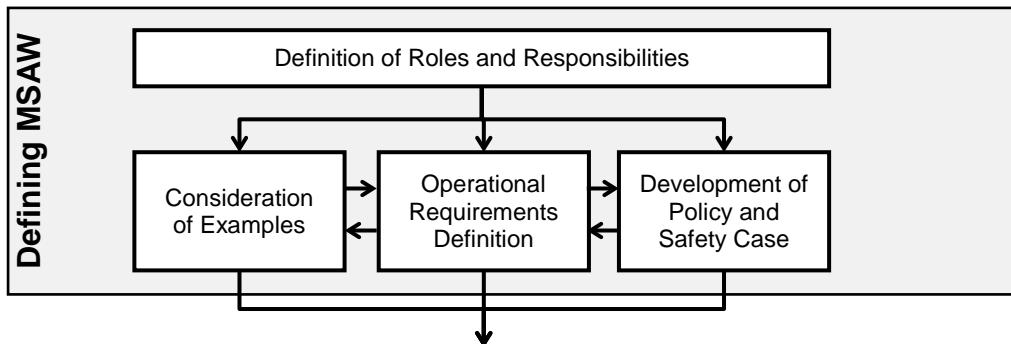


Figure 2: First phase of the MSAW lifecycle

A first step of defining MSAW is making clear and well known the roles and people inside the organisation responsible for MSAW. Three parallel processes should then be started: (a) considering a “Reference MSAW” as technical input for the following phases, (b) defining the Operational Requirements and (c) developing a specific Policy and Safety Case.

3.2 Definition of roles and responsibilities

The EUROCONTROL Guidelines for MSAW (Part I) require that:

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.

Management of MSAW can be addressed in different ways, according to the specific characteristics and constraints of the ANSP. Nevertheless, through various phases of the MSAW lifecycle, a mix of different staff will be required, including technical, operational and safety specialists. Despite the fact that developing an MSAW may appear to be a purely technical exercise, it is of paramount importance that MSAW is fit for purpose in the specific operational environment and consistent with the safety policy established by the ANSP.

In all ANSP organisations an adequate flow of information between technical, operational and safety staff is constantly required, especially in the tuning and validation phases.

The operational staff should have experience in the various areas where MSAW will be active.

Finally, an adequate involvement of safety staff should be ensured both when developing the Policy and Safety Case and when monitoring MSAW performance. For example, the role of MSAW should be adequately considered when evaluating the overall safety performance of the ANSP.

Note that roles and responsibilities can change or be adapted as far as new needs emerge in following phases of the lifecycle. However roles should remain clear and well established inside the organisation, to ensure reliable management of MSAW.

3.3 Consideration of examples

The EUROCONTROL Guidelines for MSAW (Part III) contain comprehensive implementation and optimisation examples. These examples allow obtaining an upfront understanding of the inherent complexity of MSAW and the necessary optimisation process to make MSAW effective in the specific operational environment.

As such these examples are recommended practices aimed at identifying the basic elements of MSAW and the advantages and disadvantages of various options and parameter settings.

Familiarity with Part III will ease understanding of the subsequent sections of this document.

3.4 Operational requirements definition

In general terms, operational requirements are qualitative and quantitative parameters that specify the desired capabilities of a system and serve as a basis for determining the operational effectiveness and suitability of a system prior to deployment.

This part of the MSAW lifecycle is very important, since time spent defining a set of high quality operational requirements is time spent reducing the risk of partial or complete project failure.

For MSAW, the scope of the operational requirements covers both functional and non-functional requirements, including, but not limited to, the following:

Functional requirements:

1. Capabilities or features of the system (e.g. MSAW surface definition, types of alert inhibition)
2. System capacities (e.g. number of MSAW surfaces, obstacles, etc.)
3. Requirements on environment data (both on-line and off-line)
4. HMI requirements (as far as is relevant for the system)
5. Data recording requirements

Non-functional requirements:

1. Usability requirements (e.g. clarity of alerts, ease of data input)
2. Quality attributes (e.g. reliability, maintainability, supportability, testability, safety, standards and availability requirements)
3. Constraining factors imposed externally (e.g. cost, legislation, policy)
4. Interoperability/interface requirements (e.g. physical, process, support and information interfaces to other capabilities/systems)

Defining the operational requirements of a new or modified MSAW can be a challenge, especially for individuals who have had no previous experience in either MSAW or operational requirements definition. Therefore, this section is focussed on the process of defining operational requirements.

The convention is to consider the definition of operational requirements as a three-stage process.

1. Initial Requirements capture - gather an exhaustive list of requirements
2. Requirements Analysis - analyse the list to address ambiguous, incomplete or contradictory requirements
3. Requirements Recording - record the final requirements in an operational requirements document

3.4.1 Initial requirements capture

The aim of the requirements capture stage is to produce a list of requirements without analysing them deeply. The list of requirements should be refined later during requirements analysis. During the capture stage, too narrow a focus can result in costly oversight, which can only be pre-empted through engagement with all key stakeholders early on in the process.

There are a number of techniques and tools that can be used to derive requirements. Some of the more widely used ones are:

- Key Stakeholder Workshops for the resolution of discrepancies by consensus
- Re-use of requirements (requirements from previous MSAW)
- Product research (product surveys, web searches, ANSP feedback)
- Use of guidance material (Reference MSAW System)
- Interviews with stakeholders, usually on a one-to-one basis, to facilitate detailed consultation (ATCOs, technical specialists)
- Use of a requirements checklist (see section 3.4.4)
- Brainstorming techniques are particularly suited to where requirements are considered vague (In groups of six or fewer domain specialists)
- Hazard Analysis (finding potential hazards can generate requirements for mitigation)
- System Modelling (real time or fast time, as appropriate) may be used as a facilitating mechanism
- Capability gap analysis (a study comparing the current capability to the desired future capability).
- Prototyping
- Lessons learned (from previous projects or programs)
- Use of an MSAW demonstrator to show example situations and alerts

It is suggested that a number of these techniques/tools be employed, depending on the amount of effort that is available, and the anticipated complexity of the requirements.

The people involved in the requirements capture depends to some extent on the methods employed. Nevertheless, it is always essential to involve operational, technical and safety staff in the process. The experience of operational staff should cover the entire airspace in which MSAW will be active. Important input into the requirements capture will also come from a number of technical experts who should have knowledge of MSAW, other associated ATM functions (e.g. flight data processing, surveillance data processing, data recording) and issues related to system interfacing.

The requirements checklist is a non-exhaustive list of areas that should be considered in the requirements capture, and may be used to give structure to interviews and brainstorming sessions.

Models and prototypes can be powerful tools for establishing both functional and non-functional requirements. However, the model or prototype may require a significant amount of resources to produce.

The output of the previous activities is typically a loose collection of lists of requirements and related issues. These need to be engineered into one cohesive database.

3.4.2 Requirements analysis

Requirements analysis should be undertaken by a small group of qualified staff with operational, technical and safety expertise.

The purpose of the exercise is to sort through the list of requirements obtained from the previous stage to check that each is complete and unambiguous, and does not contradict other requirements. It may be necessary to clarify some requirements with the originator.

It is also useful to organise the requirements into groups of related requirements or categories.

3.4.3 Requirements recording

The final stage is to record the requirements in an operational requirements document.

This is a living document. In discussion with manufacturers or other ANSPs, it is likely that requirements will change or be added that were not foreseen in the original requirements capture.

Requirements may also be removed. To avoid unnecessary repetition of effort, it is important that a permanent record of each removed requirement is kept, as well as the reason for its removal.

It should also be agreed with the manufacturer at which point in the development of MSAW the requirements will be frozen.

Each requirement should be:

- **Correct**

It is recommended that each requirement be reviewed for correctness, if necessary, tracing back to the originator, or originating document that led to the requirement. Ask whether the requirement is strictly true, and whether it is necessary. If the answer to either question is "no", then the requirement should be reworded, re-ranked (for importance), or deleted.

- **Unambiguous**

Each requirement should have as far as possible only one interpretation. Requirements need to be contractually taut. If not, then the supplier might misinterpret what was asked for and the recipient cannot know if they have received what was meant to be delivered and so may not know whether to accept it. An independent review of the requirements can help identify ambiguous use of language.

- **Complete**

Consider whether, given the operational requirements document alone, the product developers would be able to deliver a suitable system.

- **Consistent**

Each requirement should neither contradict nor repeat any other requirement.

- **Ranked for Importance**

Some requirements may be essential, whereas others may simply be desirable, so it is important to assign a priority to each one. This may help decision-making if, at a later date, it becomes apparent that some requirements are difficult to achieve within the anticipated budget. Requirements can be prioritised as follows:

- Key requirements are critical to the capability and the satisfaction of the operational need. They bound the contract and encapsulate the characteristics of the capability
- Priority 1, Priority 2 and Priority 3 requirements in decreasing importance. The ability to trade these requirements is to be defined within the project
- Mandatory requirements are compulsory but not unique to the capability (e.g. legislation/safety)

- **Verifiable**

It is important to consider whether reasonable means exists to check that the product meets the requirement. If a method cannot be devised to determine the product meets the requirement, then it should be reworded or removed. To satisfy the need for testability, the requirement should also be defined in precise terms. For example, replace phrases such as "immediately" and "appropriate HMI" with phrases like "within 3 seconds of the event 99% of the time", and "pop-up menu, realised by a click of the right mouse button".

- **Atomic**
There should be only one action or concept per statement.
- **Modifiable**
Avoid duplication of requirements and structure the operational requirements document to be easily modifiable.
- **Traceable**
It is often useful to be able to determine the original reason for a requirement. A requirement is traceable if its origin is clear.

3.4.4 The MSAW requirements checklist

Table 1 below outlines a number of questions that an ANSP will find useful to address in order to help define the requirements for MSAW. The list is not exhaustive, and ANSPs will no doubt need to define requirements that are not covered in the list.

The ANSP may also use parts of the checklist as a basis for compiling a list of questions for MSAW manufacturers.

Table 1: MSAW requirements checklist

1. Current and Future Operational Environment
1.1 Within which classifications/types of airspace will MSAW be adopted? Airspace Classification (e.g. Class A – G), en route, off-route, TMA, approach, departure, stacks, military airspace, danger areas.
1.2 What aerial activity is conducted in and close to the MSAW airspace? Straight flight, vertical transitions, turns, aerobatics, military operations, high energy manoeuvres.
1.3 What types of flights are of concern? Civil, Military, General Aviation, IFR, VFR, GAT, OAT
1.4 What is the nature of the traffic? Traffic hotspots close to terrain, MSAW protection around SIDs and STARs, busy periods, temporary obstacles
1.5 How is the airspace used? FUA either now or in the future, Civil/Military sharing airspace, uncontrolled flights
1.6 What is the impact of ATM procedures? Standing agreements? Silent coordination?
2. Current and Future ATM System Components
2.1 Flight Data Processing System Correlation used for MSAW eligibility? Flight plans available over area of interest? MSAW function in FDPS failure modes?
2.2 Data Recording System Recording of tracks and alerts? Recording of internal MSAW values? Sufficient to allow verification of MSAW, or alert analysis?
2.3 Other Data Inputs QNH, Temperature

3. Current and Future Surveillance

3.1 Surveillance Coverage

Coverage sufficient (especially at lower altitude)? Known problem areas? What is the operational requirement?

3.2 Track Quality

Quality of lateral and vertical track? Tracker lag? Tracking blunders? Transponder faults? Reflections?

3.3 Data Content

Turn information? Track Age? Track Quality? Mode S Data? SFL?

4. Track Eligibility, MSAW Definitions and Parameters

4.1 Eligibility

Eligibility based on tracks correlated to a flight plan and/or SSR code lists?

Tracks without Mode C?

Use of track quality? Track Age?

Are some tracks to be Inhibited (manually or automatically)?

4.2 MSAW surface definitions

Use of Digital Terrain Data, use of polygons, or both?

MSAW should use actual polygon shape or superimpose on a grid?

Constraints on grid dimensions and cell size?

Use of an obstacle data base?

4.3 MSAW exclusion areas

Number of MSAW exclusion areas?

Exclusion area shapes?

Exclusion area activation (on and off) either manually or automatically?

4.4 Regions (regions could be used to apply different predictions or parameter values according to the airspace)

Regions required (now or in future)?

Region shapes?

Region activation (on and off) either manually or automatically?

4.5 Parameters

Which parameters must be tuneable (e.g. sensitivity, false alerts)?

Parameter ranges sufficient for optimisation?

5. MSAW System Features (see Reference MSAW System for more information)

5.1 Treatment of Special Conditions (radar reflections, known transponder faults)

5.2 Conflict Detection Mechanisms (Linear prediction, Current position, Turning prediction, uncertainty etc)

5.3 Use of CFL and/or SFL.

5.4 Alert Confirmation Stage (Time of Violation Tests, Conflict Counts, Conflict Probability)

5.5 Conflict Alert Message

Supports Multi-level alarms? Contains pertinent data (TOV, MSAW volume)?

6. Issues related to HMI (where HMI requirements are an issue)

- 6.1 Effective use of colour, flashing etc. for an alert?
- 6.2 Effective use of aural alarms
- 6.3 Separate alert box used? Appropriate information in the box?
- 6.4 Display of multilevel (multi-severity) alarms?
- 6.5 Alert acknowledgement (the suppression of a current MSAW alert)?
- 6.6 Alert inhibition (the suppression of one or more tracks from MSAW processing)?
- 6.7 Display of MSAW status (to controller(s), supervisor)?

7. Tools and Support

7.1 Tools

- Data recording and playback?
- Display of internal MSAW values?
- MSAW analysis and tuning tools?
- Plot/track/flight generator to create test scenarios?
- Other display tools for MSAW surfaces, encounters or hot spots?

7.2 After Sale Support

- Support for set up and optimisation?
- Training / documentation for technical staff and controllers?

3.4.5 The implications of using digital terrain data

The use of DTED can be an attractive option for ANSPs. Because the digital data is naturally a much finer representation of the terrain than a series of hand-made polygons, its use normally results in a reduced number of nuisance alerts. This then allows the user to set longer prediction time and/or warning time parameters, resulting in a good balance between the timeliness of the alert and the nuisance alert rate.

For MSAW configurations that allow the importation of DTED, the operation of loading the data itself is normally straight forward, and generally less effort than manually constructing polygons for the whole area of interest.

Before using DTED data, ANSPs should ensure that the data is fit for purpose. The DTED product supplier should be able to provide basic information on the accuracy and integrity of the data. Nevertheless, the user should check the data independently, looking to see if there are any missing data, any gross errors, or unacceptable errors on local peaks.

Some of the most effective analyses of DTED have been done by taking two sources of data, and effectively taking the elevation differences between the two sets of data (where they cover the same ground). The analysis normally requires a specially produced computer program, which subtracts the elevation from one DTED source from another and outputs the result to a colour coded bitmap. Gaps in either data source should also be colour coded (perhaps in black or white to distinguish it from an elevation difference). The resulting bitmap is then viewed, and the user can immediately see any gaps in the data and the areas where there is significant discrepancy between the two data sources. The user may have to compare a number of data sources before it is clear which data source is actually better.

Extra checks should also be done by taking known local peaks (mountain peaks especially). A missing or erroneous peak is likely to impact MSAW performance more than an error elsewhere. Hence, the user should aim to manually check a generous portion of spot elevations against the published elevations.

3.4.6 The use of obstacle data in MSAW

The purpose of using obstacle data in MSAW is to supplement the DTED data. MSAW configurations that use DTED include a vertical margin parameter, to take account of obstacles that are not included in the terrain data, such as man-made objects, buildings, and vegetation. Nevertheless, some objects may be sufficiently tall to warrant inclusion in an MSAW obstacle data base.

The decision to include obstacles will depend on a number of factors:

- How closely the DTED models the terrain, and how closely it models the reflective surfaces (i.e. the trees and buildings)
- The vertical margin the ANSP intends to use and whether this is sufficient to cover all the tall man-made obstacles

The permanent static obstacles, such as towers, sky-scrappers are relatively easy to include in a data base. However, the user should also consider if temporary or moveable objects are also to be included, and therefore how the inclusion in the MSAW obstacle data base will be managed.

3.4.7 The use of temperature in MSAW

Pressure altimeter systems on aircraft are calibrated for the International Standard Atmosphere (ISA), which includes an assumed air-temperature at mean sea level of 15°C. In simplistic terms, every 1°C deviation from 15°C will result in a deviation from the true altitude of approximately 0.4%. That is, if the air temperature at sea level were 5°C, an aircraft altimeter indicating an altitude of 1 000 ft (after QNH correction), would in fact be at about 960 ft (assuming all other errors were negligible).

The table below illustrates the actual aircraft altitude for various combinations of indicated altitude and temperature (at MSL).

Table 2: Actual aircraft altitudes at various temperatures

Altimeter Reading	1 000 ft	2 000 ft	3 000 ft	5 000 ft	10 000 ft
0°C	940 ft	1 880 ft	2 820 ft	4 700 ft	9 400 ft
5°C	960 ft	1 920 ft	2 880 ft	4 800 ft	9 600 ft
10°C	980 ft	1 960 ft	2 940 ft	4 900 ft	9 800 ft
15°C	1 000 ft	2 000 ft	3 000 ft	5 000 ft	10 000 ft
20°C	1 020 ft	2 040 ft	3 060 ft	5 100 ft	10 200 ft
25°C	1 040 ft	2 080 ft	3 120 ft	5 200 ft	10 400 ft
30°C	1 060 ft	2 120 ft	3 180 ft	5 300 ft	10 600 ft

ANSPs should decide how temperature (particularly cold temperature) could affect the performance of MSAW in their particular environment, and possibly give further consideration of how it could practically be provided to the MSAW system, if required.

3.5 Development of a policy and a safety case

3.5.1 Development of a policy

The EUROCONTROL Guidelines for MSAW require that:

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.

The policy should be developed in collaboration with controllers who have experience of using MSAW operationally, as well as staff who understand the specific operational environment. Local factors, such as the density and type of air traffic, may be taken into account when developing the policy.

The policy statements define how MSAW is to be used. Consequently, these statements should steer much of the MSAW lifecycle, including operational requirements definition, system specification, parameter settings and controller training.

3.5.2 Development of a safety case

It is Safety Management best practice and an ESSAR4 requirement to ensure that all new safety related ATM systems or changes to the existing system meet their safety objectives and safety requirements. ANSPs and National Safety Authorities will need documented assurance that this is the case before putting the new or changed system into operation. Typically, the assurance is presented as a safety case.

Comprehensive guidance on how to develop a safety case for MSAW is contained in the “Level 2” MSAW documentation (see EUROCONTROL Guidelines for MSAW Part I, Executive Summary and Chapter 1).

An ANSP’s own documented assurance should contain the evidence, arguments and assumptions as to why a system is safe to deploy. The process of developing and acquiring the necessary safety assurance is considerably enhanced if the activities to obtain it are planned from the outset, ideally during the system definition phase of a project.

The “Level 2” MSAW documentation contains:

- Initial Safety Argument for MSAW System - Ideally, produced during the definition phase of a project to introduce a change to the ATM system e.g. to introduce MSAW; the process of developing and acquiring the necessary assurance is considerably enhanced if the safety arguments are set out clearly from the outset
- Generic Safety Plan for MSAW Implementation - Initially produced at the outset of a project as part of the project plan, but focused only on those activities necessary to provide assurance information for inclusion in a safety case; the safety plan will be subject to development and change as the project unfolds and more detail becomes available
- Outline Safety Case for MSAW System - Commenced at the start of a project, structured in line with the safety argument, and documented as the results of the planned safety assurance activates become available

4. Implementing MSAW

4.1 Introduction

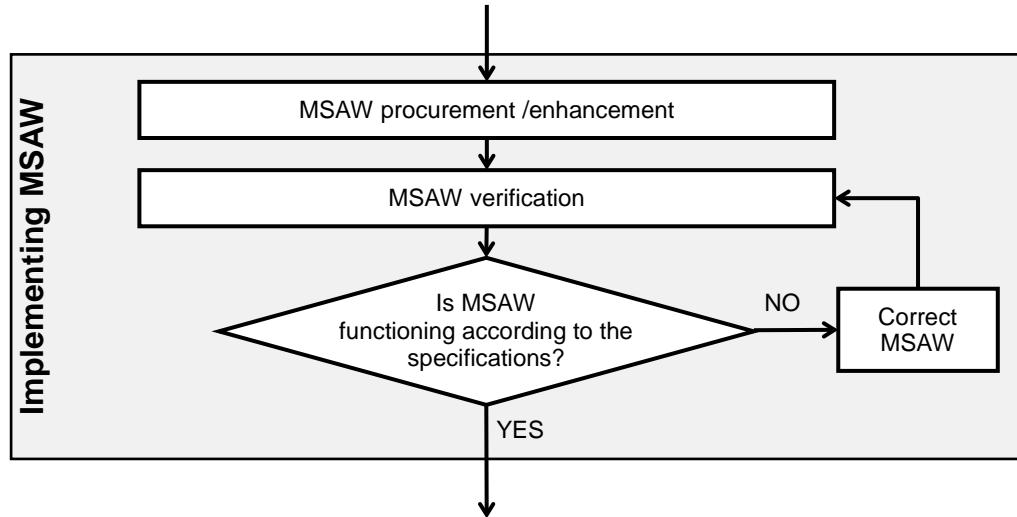


Figure 3: Phase 2 of the MSAW lifecycle

ANSPs will normally choose between two alternative options when covering this lifecycle phase: (a) purchasing an MSAW product from a manufacturer or (b) enhancing an already implemented system. For both cases guidance is provided in the following sections of this chapter and in Part III of the EUROCONTROL Guidelines for MSAW.

4.2 Procurement of MSAW

The aim of any purchase is that the delivered product is fit for purpose.

Manufacturers of MSAW have a responsibility to ensure that the products they sell are fit for operational use. Conversely, the ANSP also has a duty to inform the manufacturer of any specific requirements at an early stage.

MSAW, like other safety nets, is often included as part of a manufacturer's ATM system. If this is the case, it is important to make sure that the MSAW is appropriate.

At a very early stage in the purchase decision, it is essential that the manufacturer supplies a specification of the proposed MSAW so that the purchaser can assess if the MSAW will be appropriate for their needs. It is also helpful if at the earliest opportunity, the manufacturer is able to demonstrate the MSAW, and explain the functional aspects. If the MSAW is part of an ATM system to be purchased, then the HMI and visual/aural aspects of the MSAW alerts should also be demonstrated.

The purchaser should review the MSAW specification in detail to ensure that the system will not only be fit for current use, but can be configured to meet anticipated future needs (such as changes to airspace, or new input data). The purchaser should also seek the manufacturer's advice, to check whether the MSAW will meet the purchaser's needs. It is likely that several meetings between the respective experts will be required specifically to discuss requirements, system capabilities and capacities.

If the MSAW is not being designed from a set of operational requirements, it will be useful at the outset for representatives from both the manufacturer and the purchaser to compile a list of relevant questions. An example list is given in Table 3 below:

Table 3: Example list of relevant questions

What is the extent of the airspace to be covered by MSAW?
What is the nature of the air traffic (TMA, en route, approaches, departures, stacking)?
What are the main features of MSAW, and are they in accordance with aircraft behaviour, tracker behaviour and local operational procedures? (Perhaps think about how much manoeuvring occurs, the number of tracks from radar reflections, and whether reliable CFL or SFL data is available)
What SDP (tracking) data will be provided to MSAW, and is it of sufficient coverage and quality?
What other data will be supplied to MSAW? Flight plan data? Data input by the controller?
How will MSAW alerts be presented to the controller?
Does the facility exist for the controller to be able to manually inhibit alerts?
How are parameters set, and regions defined?
How are terrain and obstacles modelled in the operational system?
Is the maximum number of polygon volumes sufficient for current and future needs?
Can exclusion regions be dynamically activated / deactivated?
How many exclusion areas can be defined?
Are other MSAW capacities sufficient for both current and future needs?
Do the parameters (or range of values) allow MSAW to be optimised for the airspace?
What MSAW analysis tools are provided?
Is the MSAW capable of recording its internal values, and are they sufficient for testing?
Who will test MSAW? And how will it be tested?

The answers to these questions will help both the purchaser and the manufacturer determine whether the purchaser's requirements can be met.

The purchaser may wish to ask the manufacturer for specific features, or the manufacturer could offer a number of advanced features. With any of the advanced features, it is important to make sure that it is relevant in the airspace of interest and local operational procedures.

MSAW should be subject to factory acceptance testing (FAT) and site acceptance testing (SAT).

It is normal practice for not only the manufacturer to perform tests on the system but also the purchaser. The purchaser in particular will want to test the system to make sure that:

- It behaves as specified
- It is fit for operational use

The manufacturer should be able to supply tools and, if necessary, human resources to help the purchaser test MSAW.

4.3 Enhancement of an existing MSAW

4.3.1 Introduction

This section provides guidance on how to manage the enhancement of an existing MSAW.

The need to enhance MSAW is very often driven by a need to solve performance issues. In particular, it is not unusual for one or more of the following problems to exist:

- MSAW is giving irrelevant alerts (e.g. alerts for non-eligible aircraft)
- MSAW is producing too many false or nuisance alerts
- MSAW is not providing sufficient warning time, or provides sufficient warning time only in a limited number of situations

As well as improving alerting performance, MSAW can also be enhanced by making improvements to the presentation of the alert, or the controllers HMI. A number of HMI options are described in section 4.5.

Enhancing MSAW is normally less expensive than buying a new one from scratch. In any case, a new MSAW may not necessarily solve the original problem(s). Furthermore, the ANSP is generally familiar with how their MSAW operates, and can often foresee how MSAW will perform after improvements have been implemented.

Nevertheless, in order to make the improvements, the ANSP must commit some resources to the task, and must either already have a good technical understanding of MSAW, or draw on external technical expertise.

4.3.2 The improvement process

The improvement process can be broken down into a number of essential steps:

- Identifying and understanding the nature of the problem(s)
- Designing appropriate solution(s)
- Implementing the change
- Measuring the effect of the change

Identifying and understanding the nature of the problem is the crucial first step to designing an appropriate solution. In some cases, the precise nature of the problem will be revealed simply by looking at a controller display.

However, in many other cases, the only way to fully comprehend the problem is to record a sample of traffic, and analyse in detail the situations that trigger the problem. This analysis is greatly aided by the availability of a complete and accurate specification of the MSAW algorithms.

It is important at the analysis stage to involve both technical and operational staff. This is because technical staff alone may identify solutions that would not be operationally appropriate.

If a number of problems are present, it may be appropriate to implement one solution at a time, in order to test it and measure its effect separately.

An MSAW model is an ideal instrument for testing many proposed improvements to MSAW, and allows the effect of the change to be measured before it is put into the operational system. However, if a model is not available, an alternative could be to use an MSAW running on a non-operational partition of the ATC system.

When adding new logic to MSAW, it is essential to include parameters that will allow the new logic to be fully tuned, and bypassed in the event that the solution does not work as foreseen.

If the solution is complex, ANSPs should consider how risk can be reduced, perhaps by implementing the solution in stages, or by introducing it at a smaller ATC centre first for a trial period.

4.4 Guidelines for improving the alerting performance of MSAW

The most important step is to identify and fully understand the nature of any deficiencies with MSAW. Figure 4, below, is an idealised troubleshooting process that shows the steps that should be taken when trying to solve problems related to MSAW performance. The feedback loop in the process ensures that if MSAW is changed (parameters, algorithms or external systems modified), then the problem is re-reviewed and other changes made as necessary. For example, having modified the algorithms, it may be necessary to re-evaluate the MSAW parameter settings.

It is not always necessary for MSAW to be technically enhanced. Many problems can be overcome or reduced by changing the MSAW parameters. Further, making parameter changes might provide a temporary solution to a problem, whilst a better long-term solution is being investigated.

Similarly, some problems could be resolved simply by updating a list of SSR “controlled” codes. It is important to review these codes regularly and make sure they are up to date. It should be considered that specific SSR codes may be assigned to aircraft that are intentionally close to the terrain, such as police helicopters, air ambulances, pipeline/power line inspection flights, survey helicopters, military exercise/low level flights, aerobatic displays and other special events. These SSR codes should be inhibited from MSAW processing in order to prevent continuous nuisance alerts.

Sometimes, a very simple solution may be found which can make a significant contribution to the performance of MSAW. In particular, some deficiencies may be discovered by carefully inspecting the code or the specification. For instance, some things to check for are:

- Check that the eligibility criteria are finding all the aircraft of interest (i.e. they are not removing relevant aircraft from MSAW processing)
- If using a step-wise prediction method, check that the step time is sufficiently short so that no conflicts are missed
- Make sure that the alert confirmation stage gives priority to alerting when the situation is imminent (any tests for imminent conditions must not wait for a count of conflict hits to build up)

Certain problems, such as erroneous tracks (due to tracking blunders, radar reflections or erroneous transponders) are not usually solved by tuning the MSAW parameters and are likely to need specific enhancements to the tracker, or identification and correction of offending transponders. For example, trying to avoid alerts from tracking blunders by setting a large conflict count may be inappropriate because it would reduce the overall performance of the MSAW system. Instead, problems with the tracks introduced to MSAW should, if possible, be solved within the wider surveillance system.

Furthermore, MSAW performance may be masked if there are an overwhelming number of false alerts from erroneous tracks. Therefore it is best to deal with these types of unwanted alerts before trying to tune the parameters for optimum alerting performance.

Once most of the problems have been resolved, further improvements to MSAW may be made, for example, by the introduction of new algorithms or the use of digital terrain data.

ANSPs should select enhancements that are in accordance with how aircraft behave in the airspace and local operational procedures. For example, use of CFL or SFL is best considered only if the CFL is input as part of normal ATC procedures or if SFL is available from mode S enhanced surveillance.

The ANSP should review the overall effect of any changes to the MSAW system on alerting performance, and should consider whether some of the other parameters need re-tuning to redress the balance between warning time and nuisance alert rate. For example, if CFL or SFL is used, some parameters may be increased, since there may be more scope to increase the warning time with little effect on the nuisance alert rate.

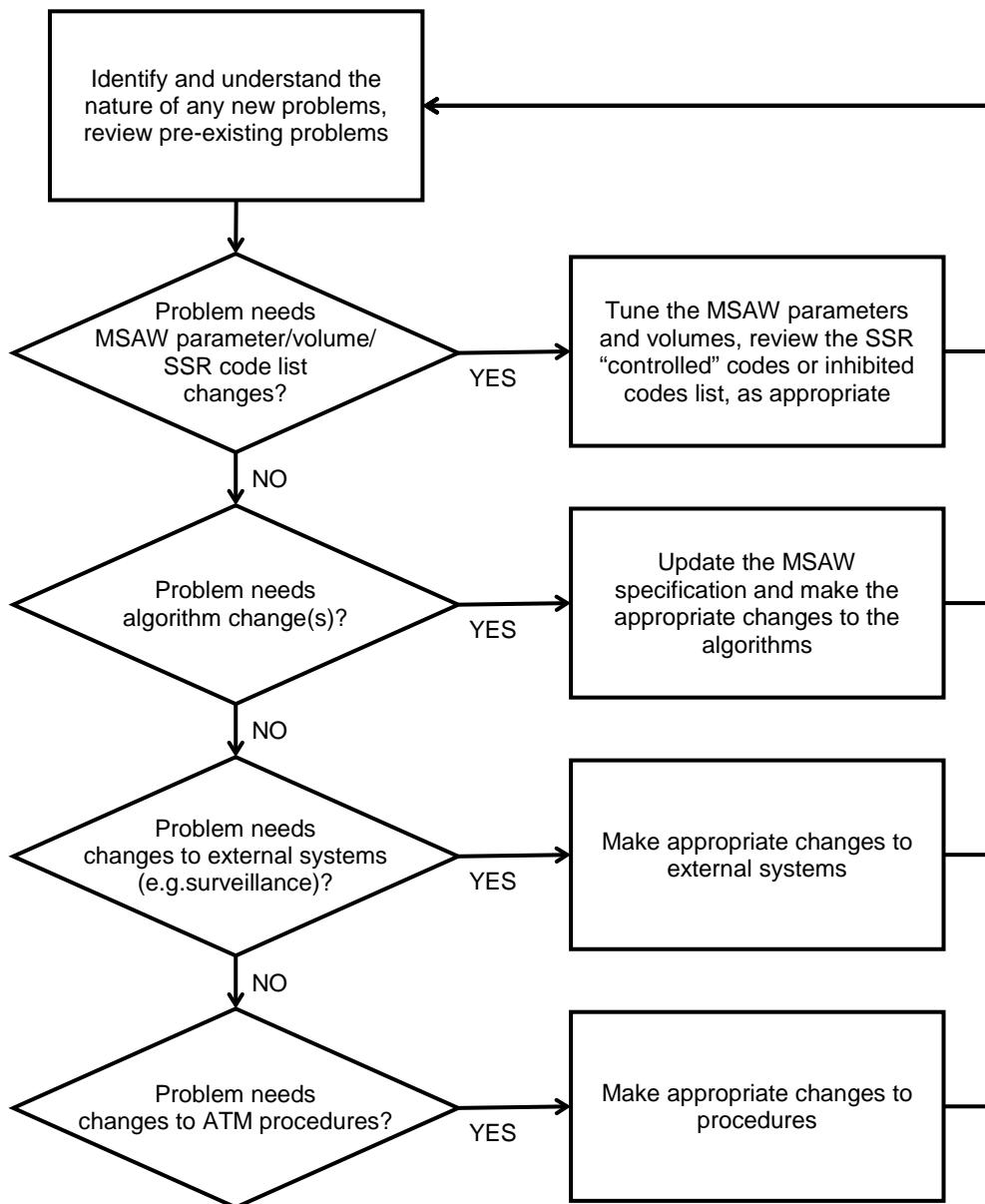


Figure 4: Idealised troubleshooting process for MSAW

4.5 HMI options for MSAW

4.5.1 Introduction

Controller's displays vary between implementations, and likewise so does the presentation of MSAW alerts, and MSAW related information.

The purpose of this section is not to promote one type of presentation over another, but to describe a number of options and explain what needs to be considered when deciding on an appropriate HMI.

The most important aspect of an alert is that it should be clear and unambiguous. Even if MSAW is the only source of alerts, the HMI should be designed bearing in mind that other sources may be added in the future.

4.5.2 Requirement for presentation of alerts

The EUROCONTROL Guidelines for MSAW Part I require that:

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 system's 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.

4.5.3 Visual presentation

An alert is usually indicated visually either by the addition of a short coloured (usually red or yellow) string ("MSAW", "T" or "LA") in the track label, a change of colour or a flashing of part of the track label, or a change in the track symbol colour.

4.5.4 Audible presentation

An audible element to the alert can help draw the controller's attention to a conflict.

The alarm should be clear and unambiguous, and should be audible to the relevant controller.

On the other hand, alarms that are too frequent, too loud or unpleasant will become a nuisance. Continuous alarms may also be a nuisance, and furthermore may overlap with controller's RT instructions to the pilot, potential causing alarm and confusion in the cockpit.

The precise characteristics of the audible alarm must be carefully engineered, taking into consideration other competing noises in the control room and the frequency of MSAW alerts.

4.5.5 Alert inhibition

Alert inhibition can be applied to one or more aircraft, not necessarily those that are currently alerting, and suppress them from alerting.

Tracks are selected for inhibition by the controller on his display, usually based upon SSR codes or call signs.

Note the requirement from the EUROCONTROL Guidelines for MSAW Part I:

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

4.5.6 Controller inputs

The HMI for any controller inputs should be as user-friendly and efficient as possible.

4.5.7 MSAW status information

Note the requirement from the EUROCONTROL Guidelines for MSAW Part I:

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

It should be immediately clear to controllers and supervisors when MSAW is not fully functioning.

4.6 MSAW verification

4.6.1 Verification methods

The aim of verification is to check that MSAW is behaving as described in the specification. Therefore, verification relies on the availability of a detailed and accurate specification.

The level of verification that can be done will also depend fundamentally on the data recording capabilities of the system. Guidelines for recording MSAW data are described in detail in the EUROCONTROL Guidelines for MSAW Part III.

It is normally the responsibility of the manufacturer to make sure that MSAW is working as specified. Nevertheless, it is likely that the purchaser will want to check the same, and may either require evidence of verification, or the facility to make its own checks.

4.6.2 Verification using an MSAW model

A model of MSAW (written to the same specification) can be an invaluable tool for verification.

For an accurate MSAW model to be produced, it is absolutely essential that the specification is complete and unambiguous. The specification should include the algorithms, parameters, trace message formats, and timing characteristics of MSAW.

When using an MSAW model, the steps that should be followed are:

- Produce or acquire a detailed and accurate specification of the MSAW algorithms
- Produce the operational MSAW; the operational MSAW should be made capable of outputting trace (or debug) messages containing pertinent internal values, and flags at decision points
- At the same time as the operational MSAW is under production, other engineers should produce an MSAW model to the same specification; the MSAW model should be made capable of producing the same trace messages
- Design and produce test scenarios to exercise all aspects of the MSAW logic; all essential information, such as parameter values, MSAW surface definitions and QNH must also be specified as part of each test (a number of example test scenarios are given in the EUROCONTROL Guidelines for MSAW Part III)

Note: For test scenarios, the terrain and obstacle model, parameters and QNH values do not have to be realistic, or even close to those that will be used operationally. The purpose of the tests is to ensure that all aspects of the MSAW logic are provoked. For some tests it may be convenient to use extreme parameter values).

- Input the test scenarios into the operational MSAW, recording the surveillance data used by MSAW, the alerts and trace messages
- Input the same test scenarios into the MSAW model, recording the alerts and trace messages; to ensure the surveillance data are identical to those used by the operational MSAW, it may be necessary to use the surveillance data recorded from the operational MSAW in the previous step

- Compare the alerts and trace messages from the operational system and the model; in principle, this could be done manually, however, if there are a number of tests, automatic comparison tools will be invaluable at this stage; any differences between the two must be investigated to check the reason for the difference; if the model is incorrect, this can be quickly fixed; if the operational MSAW is incorrect it will have to be fixed and the tests rerun.

Note: It is also possible that a difference between MSAW and the model highlights an ambiguity in the specification, which should be corrected.

- Repeat the previous three steps until all the differences have been resolved
- Input operational traffic into the operational MSAW, recording the surveillance data used, the alerts and trace messages (operational traffic is useful because it contains aircraft geometries and conditions that may have been overlooked in the design of the test scenarios)
- Input the same operational traffic into the MSAW model, recording the alerts and trace messages; again, to ensure the surveillance data are identical to those used by the operational MSAW, it may be necessary to use the surveillance data recorded from the operational MSAW in the previous step
- Compare the alerts and trace messages from the operational MSAW and the model, resolving any differences
- Repeat the previous three steps until all the differences have been resolved

4.6.3 Verification without an MSAW model

The use of an MSAW model for verification requires a significant investment of time and resources. If such investments are prohibitive, verification can be done without an MSAW model. However, the level of verification does still rely very much on a detailed specification and sufficient recording capabilities of the operational MSAW.

Without an MSAW model, one approach to verification is:

- Produce or acquire a detailed and accurate specification of the MSAW algorithms
- Produce the operational MSAW; the operational system should be able to produce trace (or debug) messages containing pertinent internal values, and flags at decision points
- Design and produce test scenarios to exercise all aspects of the MSAW logic; the terrain and obstacle model, parameter values and QNH required must also be specified as part of each test

Note: Some tests, can be designed such that the passing of the test is indicated by the presence or absence of an alert.

- Input the test scenarios into the operational MSAW, recording the surveillance data used, the alerts and trace messages
- Check that the expected alerts are present, and there are none that are not expected
- For a selection of the tests, manually check that pertinent values (e.g. time of violation) are correctly computed
- For a selection of the tests, manually check the alerts and trace messages against the specification; it should be possible to follow the logical path by comparing the computed values and flags to the algorithms in the specification
- Repeat the previous four steps (as necessary) until all issues have been resolved

5. Optimising MSAW

5.1 Introduction

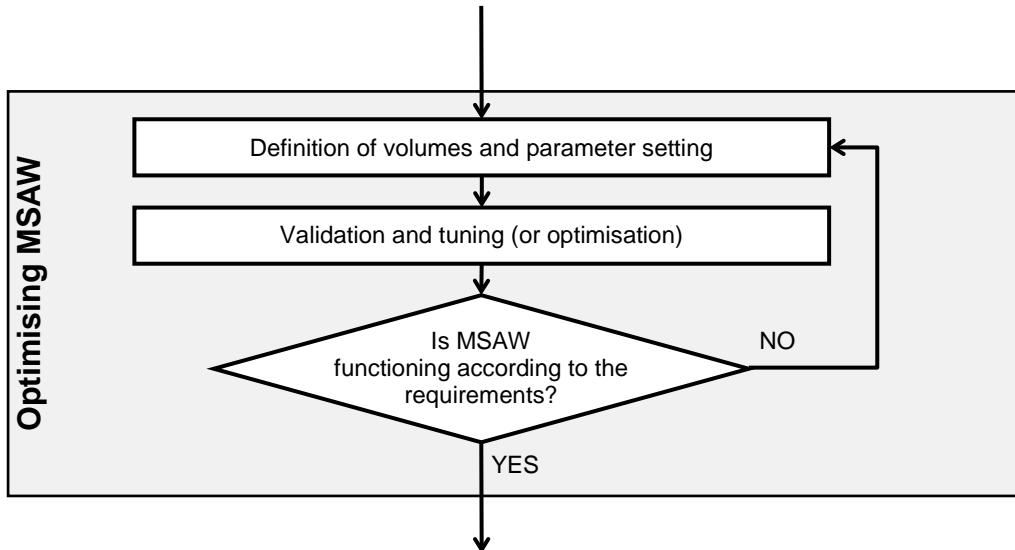


Figure 5: Phase 3 of the MSAW lifecycle

The objective of MSAW optimisation is tuning the MSAW volumes and parameters to meet the requirements laid out in the EUROCONTROL Guidelines for MSAW Part I:

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

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

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-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.

Meeting such requirements also means optimising the MSAW for the specific needs of the local environment and trying to achieve the best balance between warning time and nuisance alert rate. It is not a one-off activity but a recurring activity throughout the operational life of MSAW in order to keep MSAW optimised for the ever changing operational environment.

Essential elements of this process are: (a) the Definition of the MSAW parameter setting and (b) the Validation and Tuning. The two activities are repeated iteratively several times in order to provide as much warning time as possible, whilst keeping the number of unwanted alerts to an acceptable level and maximising the number of wanted alerts.

Comprehensive Guidance to appropriate parameter values is given in EUROCONTROL Guidelines for MSAW Part III, with suggestions on how to define parameters.

The material includes guidance to parameter optimisation for the reference MSAW system, optimisation concepts, and the optimisation procedure.

5.2 Overview of parameter optimisation

At the most basic level, parameter optimisation requires two things:

1. The capability to quantitatively measure the performance of MSAW, given certain surveillance data as input.
2. The capability to alter the MSAW volumes and parameter settings, so the results of various configurations can be compared.

The method presented in EUROCONTROL Guidelines for MSAW Part III is highly recommended because it includes quantitative measures of MSAW performance, and once in place is fast and efficient. However, the method does also require the use of large samples of recorded data, the use of various tools for MSAW modelling, visualisation and encounter classification. All in all, the process requires a significant commitment of resources to the task.

5.3 Overview of the parameter optimisation method

5.3.1 Overview of parameter optimisation tools and files

Figure 6 shows the tools and data files that are appropriate for MSAW parameter optimisation. Tools or processes are indicated in bold type, files are shown in normal type.

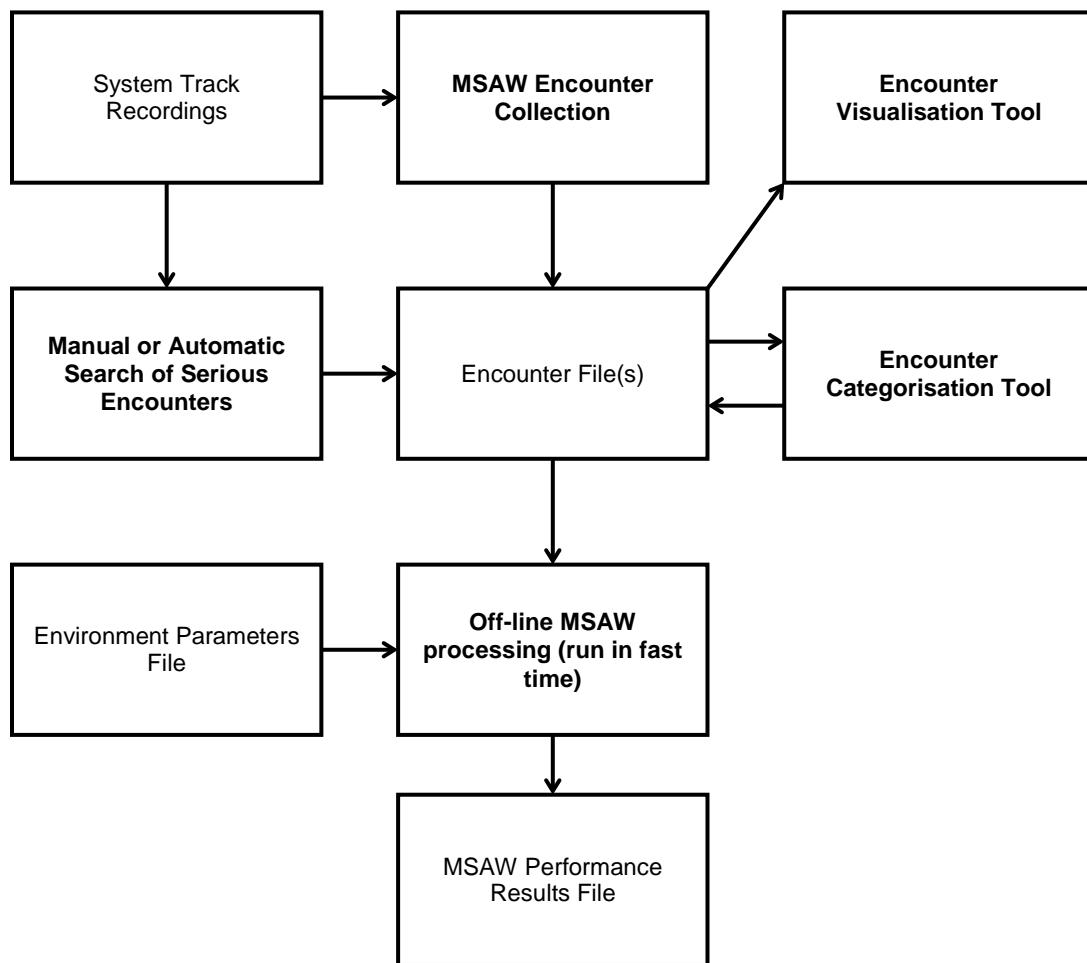


Figure 6: Tools and files required for parameter optimisation

5.3.2 Encounter collection

The first stage of the optimisation process is the collection of situations of interest in one or more “encounter files”. The purpose is to compose a set of situations suitable for MSAW performance analysis. To this end, the encounter file must contain situations that give rise to both “wanted” and “unwanted” alerts. The unwanted alerts are relatively simple to find, since these will occur in any sample of general traffic system tracks. However, the wanted alert encounters are less common and may need to be extracted from historical system track recordings.

5.3.3 Encounter files

The encounter files comprise the system tracks that are of potential concern for MSAW.

5.3.4 Encounter categorisation process

The purpose of encounter categorisation is to classify each situation in the encounter file into one of the following categories:

Table 4: Definition of encounter categories

Category 1	ALERT NECESSARY – the situation involved a serious deviation below safe altitude or avoided terrain by a late manoeuvre.
Category 2	ALERT DESIRABLE – although there was no serious deviation below safe altitude, an alert would have been useful in drawing the attention of the controller to the situation.

Category 3	ALERT UNNECESSARY – an alert was unnecessary for the satisfactory resolution of the situation but would be “predictable” or understandable by the controller.
Category 4	ALERT UNDESIRABLE – the situation presented little threat of deviation below safe altitude and an alert would be distracting or unhelpful.
Category 5	VOID – This situation is not to be used for optimisation. For example, it may be a false situation caused by erroneous track data, or it may occur in a region of airspace not covered by MSAW.

The encounter categorisation process needs to be done before inputting the encounter file into the MSAW model.

5.3.5 Encounter visualisation and manual categorisation

Because the encounter categorisation process is somewhat subjective, some means of examining individual encounters will be required, in order to do a manual categorisation. Software that generates a printed diagram showing the situation in lateral and vertical view is recommended. The diagram should also show pertinent data such as minimum altitudes (MVA, MOCA, MSA) and the terrain and obstacles model. An assessment may then be made of the borderline situations to assign an appropriate category. For manual categorisation, it may also be useful to take advice from controllers as to whether an MSAW alert is desirable for particular borderline situations.

5.3.6 The off-line MSAW processing

Having categorised all the encounters, they are input into an off-line MSAW process.

The off-line MSAW process must be functionally identical to the operational system. Also, the process should be able to run in fast time, so that several weeks of traffic may be processed very quickly; during optimisation the same data sets will need to be processed by the model many times with varying environment parameter sets.

The off-line MSAW process will record various data, such as described in EUROCONTROL Guidelines for MSAW Part III.

5.3.7 MSAW performance results

The MSAW performance results file contains details of the performance test run, overall performance statistics as well as the timing and details of each of the alerts.

The test run details must include:

- The names of all environment and encounter files input into the model
- Identification of encounters that have been processed

The overall statistics must include the following measures:

- The number of encounters of each category
- The number and percentage of alerts of each category
- The mean warning time for wanted alerts

The details of each alert must include:

- Identification of the aircraft encounter
- The time and duration of the alert
- The polygon volume or cell that was predicted to be penetrated (as relevant)

5.3.8 Requirements for MSAW performance

In essence, the purpose of the optimisation process is to maximise the number of wanted alerts, providing as much warning time as possible whilst keeping the number of unwanted alerts to an acceptable level.

Possible requirements for MSAW performance are listed in Table 5.

Table 5: Possible MSAW performance requirements

Performance Indicator	Maximise / Minimise	Required Performance	Preferred Performance
% of Category 1 encounters alerted	Maximise	$\geq 95\%$	100%
% of Category 2 encounters alerted	Maximise	$\geq 80\%$	$\geq 90\%$
% of alerted encounters which are Category 3, 4 & 5	Minimise	$\leq 75\%$	$\leq 50\%$
% of Category 3 encounters alerted	Minimise	-	$\leq 30\%$
% of Category 4 encounters alerted	Minimise	-	$\leq 1\%$
% of Category 5 encounters alerted	Minimise	-	-
% of Category 1 and 2 encounters where adequate warning time exists which give less than adequate warning time	Minimise	$\leq 45\%$	$\leq 35\%$
Mean warning time achieved for Category 1 and 2 encounters where adequate warning time exists	Maximise	$\geq 90\%$ of adequate	$\geq 95\%$ of adequate
Mean achieved warning time for Category 1 and 2 encounters where adequate warning time does not exist	Maximise	$\geq 70\%$ of mean objective warning time	$\geq 75\%$ of mean objective warning time

In order to maximise performance, repeated runs with different MSAW adaptations are generally required. Guidance for parameter settings is given in EUROCONTROL Guidelines for MSAW Part III.

5.4 Alternative parameter optimisation strategies

There are a number of strategies that may be adopted by ANSPs to ease the burden of full parameter optimisation.

5.4.1 Using artificial scenarios

Firstly, it may be possible to generate a large number of artificial scenarios, including wanted alerts and unwanted alerts. This would avoid the need to collect real data, or search for serious encounters.

Scenario generators may be available for producing individual encounters, using track script files. (These scripts include track start positions, turns, climbs etc.). If scenarios are generated individually, then encounters can be designed that are either definitely “wanted alerts” or definitely “unwanted alerts”. This approach would avoid the need for an encounter categorisation tool.

No matter how the scenarios are generated, they will need to include a large variety of different geometries and manoeuvres in all the airspace of interest.

Ultimately, the success of this approach will depend on how well the scenarios simulate the real traffic.

5.4.2 Adapting existing visualisation tools

Visualisation tools that allow tracks and MSAW alerts to be displayed are already available to ANSPs.

With a small amount of effort it may be possible to modify other track display tools to include MSAW alerts. If this is not possible, the timing of each alert could still be marked on a picture using off the shelf software.

5.4.3 Using real MSAW systems

If a version of MSAW is available that is not running on the operational partition of the ATC system, then this could be used, instead of producing an MSAW model. This MSAW must be functionally the same as the operational one.

For example, in some ATC systems, MSAW is available in a test partition.

Whereas a model can run in fast time, a test MSAW will be limited to (more or less) real time. To save manual effort, all the encounters may be best injected into MSAW as surveillance data in one large data sample. There is no reason why a large number of aircraft encounters could not be compressed into a fairly short timeframe, reducing the time between each test run to a tolerable level.

The MSAW must be capable of taking user-defined parameters and recording the alerts that are produced, and these alerts must be attributable to each encounter for later analysis.

As part of the optimisation, it is essential that the recorded alerts can be presented in a form that allows the user to assess the performance of MSAW. It may be necessary to produce a tool that takes the recorded alert file and summarises the results in a text file. The information presented should include as a minimum the identity of each encounter, whether the encounter has alerted and the time and duration of each alert. Other useful information would include, positions and heights of the aircraft at the start of the alert, the MSAW surface (polygon) or terrain cell relevant to the alert, and if possible, an identification of whether the alert is wanted.

5.4.4 Identifying alert hotspots

Identifying the geographical locations where the alerts tend to happen can be very informative, and can help the user to optimise the MSAW volumes and parameters. The user is also able to assess whether particular sectors would see more alerts than others.

A plan view presentation is required upon which the start point of each MSAW alert is depicted. The data used to show the alert positions should be taken from an extensive period of real data (recorded MSAW alerts), or alerts from an off line MSAW model.

5.4.5 Warning time measures for MSAW

EUROCONTROL Guidelines for MSAW Part III describes the calculation of warning time for measuring MSAW performance. This is quite a complex process requiring calculation of the point of risk, as well as an analysis of the situation to determine the maximum possible warning time.

As a simple alternative, it is often sufficient to compare the timing of the alerts between different runs (of the MSAW model or the test MSAW). Although this will not give an absolute measure, it will provide a very useful comparative measure of the warning time performance, allowing the system to be optimised.

6. Operating MSAW

6.1 Introduction

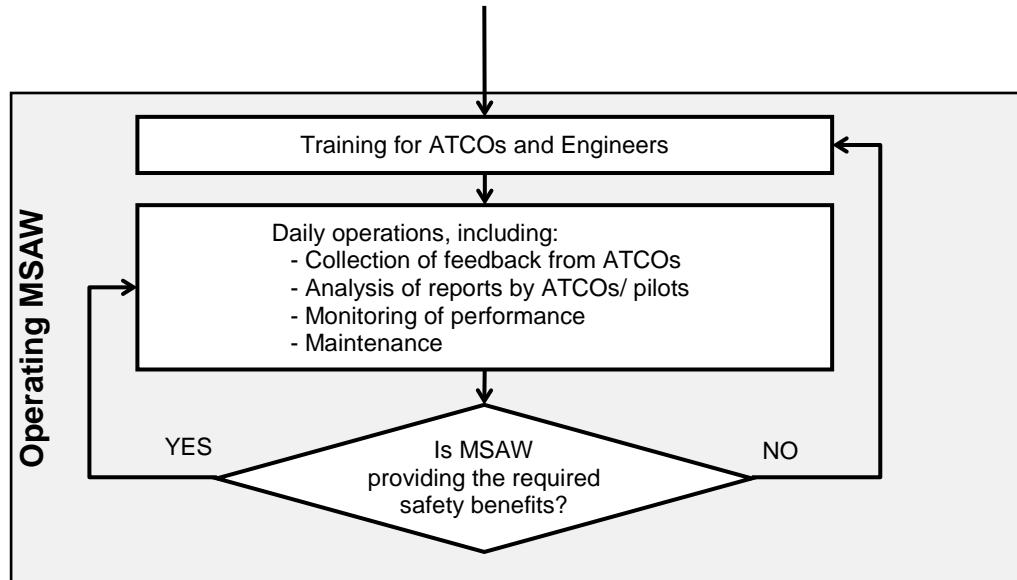


Figure 7: Phase 4 of the MSAW lifecycle

This chapter provides guidance to ANSPs in the operation and monitoring of MSAW, and also in appropriate training.

6.2 Training for ATCOs

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. in the event of sudden manoeuvres).

Training should be designed to promote appropriate operational use of MSAW and to prevent misuse. Training should include, amongst other things:

- The role of MSAW in the provision of ATS
- Differentiation between safety nets and controller's tools
- The difference between airborne safety nets (GPWS) and ground-based safety nets (MSAW)
- How MSAW detects conflicts (indicating the main features of MSAW)
- Differentiation between desired and undesired alerts
- Which aircraft are eligible for MSAW
- The airspace in which MSAW is active

- The use of flight data in MSAW processing and the consequences
- How MSAW alerts are displayed and acknowledged
- How MSAW performs in various situations (play back of MSAW situations helps here)
- What action to take in the event of an alert
- What action to take in the case that MSAW is not available
- Procedures for feedback of MSAW performance (this helps further optimisation)

Controller training on MSAW should be given before using MSAW, and again after significant changes to MSAW. Refresher training after a certain time is recommended and should comprise:

- A summary of the topics listed above
- Significant changes made to MSAW since the previous training
- Known unexpected behaviours of MSAW

A number of tools, such as ATC test partitions, ATC simulators, MSAW models or various types of situation replay media (e.g. video), and 3D visualisations are all relevant, and may be used to show example situations to controllers.

6.3 Training for engineers / operational analysts

In this context, engineers are the operational analysts responsible for the setting up, optimisation and maintenance of MSAW.

Most importantly, engineers should understand how their MSAW works; requiring that they become familiar with the MSAW specification. If no specification is immediately available, then the manufacturer should be able to supply one.

Some description of algorithms is essential for teaching new technical staff about MSAW. Therefore, if the specification is of poor quality, or is not available from the manufacturer, then it may be necessary for an engineer to examine the source code, and to precisely document the MSAW algorithms.

Engineers should then be provided with the tools and take time to become skilled in MSAW alert analysis and MSAW system optimisation.

It is a useful exercise to collect and analyse all MSAW alert situations, not only to aid parameter tuning, but to provide informative examples that can be shown to engineers, ATCOs and other staff.

The more the engineer analyses alerts, the more the engineer will understand the specification, and how the MSAW parameters affect performance.

It is a useful exercise to compare the specific MSAW system with the MSAW System in EUROCONTROL Guidelines for MSAW Part III, and furthermore Part III provides detailed advice on parameter setting, and optimisation.

6.4 Analysis of pilot/ATCO reports

It is good practice to analyse the performance of MSAW for all reported incidents and safety significant events. The analysis of individual situations can help the user to choose suitable parameters and identify potential improvements to the MSAW algorithms.

Furthermore, it is useful to keep as large a sample as possible of historical incidents for parameter optimisation.

6.5 Monitoring of MSAW performance

It is good practice to analyse all safety significant events regardless of whether they result in an MSAW alert. During an analysis of such events, MSAW parameters and volumes (and if necessary, algorithms) should be carefully considered, since it may be that some changes to the MSAW settings are identified that could potentially improve MSAW performance. Nevertheless, any changes to the settings are best tested with an off-line MSAW model before implementation in the operational system.

Monthly alert rate figures over the course of a year can help ensure that the alert rate stays within a tolerable level. Additionally, occasional analysis of the alert hot spots on an appropriate display may help to ensure that MSAW remains relevant to the airspace and the traffic environment.

6.6 Maintenance

MSAW SSR code files should be updated to reflect changes in SSR code allocations, otherwise MSAW performance is likely to gradually degrade. It may be necessary to update these files several times a year.

Regular parameter optimisation is recommended to ensure that the MSAW performance improves rather than degrades following changes to the air traffic environment.



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