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EUROCONTROL Guidance Material for Area Proximity Warning

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Abstract

This document contains comprehensive guidance material to assist in implementing the EUROCONTROL Specification for Area Proximity Warning. It covers the full APW lifecycle, including definition of objectives; implementation or change; tuning and validation; as well as operating and monitoring.

Keywords

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CONTENTS

Note: Appendices are contained in separate documents

EXECUTIVE SUMMARY

This document contains comprehensive guidance material to assist in implementing the EUROCONTROL Specification for Area Proximity Warning. Specifically, the document contains guidance related to the APW lifecycle, including:

- Defining APW (Specification of objectives)
- Implementing APW (Procurement or Enhancement)
- Optimising APW (Tuning and Validation)
- Operating APW (Training and Monitoring)

1. INTRODUCTION

1.1 Alternative Names for Area Proximity Warning

In this document and throughout the guidance material all references to the safety net use the terminology Area Proximity Warning (APW). Other names exist for what is essentially the same or a very similar type of system, including:

- APW Airspace Penetration Warning
- RAI Restricted Area Intrusion
- DAIW Danger Area Infringement Warning
- CAIT Controlled Airspace Infringement Tool

1.2 Purpose of this Document

APW is 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.

The European Convergence and Implementation Plan (ECIP) contains an Objective (ATC02.5) for ECAC-wide standardisation of APW in accordance with the EUROCONTROL Specification for Area Proximity Warning.

The EUROCONTROL Specification for Area Proximity Warning 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 this document is to provide practical guidance material to assist in implementing the EUROCONTROL Specification for Area Proximity Warning. The guidance material covers the full APW lifecycle.

1.3 Structure of this Document

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

Chapter 3 elaborates organisational issues regarding APW, including definition of roles and responsibilities, consideration of the Reference APW System, definition of operational requirements, and development of a policy and a safety case.

Chapter 4 contains a guide to APW System procurement and improvement.

Chapter 5 addresses APW System tuning and validation aspects.

Chapter 6 highlights APW System management and training issues.

This document contains the following appendices, most of which can be used as stand-alone documents for particular purposes:

Title	Purpose
Appendix A: Reference APW System	Detailed technical explanation of typical implementation details of APW 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 a starting point for APW safety assurance work in a particular local context.
Appendix B-1: Initial Safety Argument for APW 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 APW 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 APW 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 APW	Assists in identifying potential financial implications of standardisation of APW in compliance with the EUROCONTROL Specification for Area Proximity Warning.
Appendix D: Case Study	A document describing the (partial) application of the optimisation and safety assurance guidance material in a demanding environment.
Appendix D-1: Enhancement of APW for ATCC Semmerzake	Identifies potential solutions for a number of deficiencies.

1.4 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.

1.5 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.
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.
false alert	Alert which does not correspond to a situation requiring particular attention or action (e.g. caused by split tracks and radar reflections).
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.
human performance [Doc 4444]	Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.
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.*

1.6 Abbreviations and Acronyms

ANSP	Air Navigation Service Provider
APW	Area Proximity Warning
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATS	Air Traffic Service
CFL	Cleared Flight Level
EATMN	European Air Traffic Management Network
EC	European Commission
ECAC	European Civil Aviation Conference
ECIP	European Convergence and Implementation Plan
ESARR	EUROCONTROL Safety Regulatory Requirement
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
OAT	Operational Air Traffic
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
SAT	Site Acceptance Test
SES	Single European Sky
SMS	Safety Management System
SRC	Safety Regulatory Commission
TOV	Top of Violation
VFR	Visual Flight Rules

1.7 Relevant Material from the EUROCONTROL Specification

The EUROCONTROL Specification for Area Proximity Warning should be referred to for a description of the APW concept of operations.

Furthermore, chapter four of the EUROCONTROL Specification for Area Proximity Warning contains specific requirements, which are referred to in relevant sections of this document.

2. THE APW LIFECYCLE

2.1 Overview of the APW Lifecycle

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

Figure 2-1 is a concise representation of the whole lifecycle. Each phase is covered by appropriate guidance in the document.

2.1.1 Defining APW

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 APW. 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 APW, based on a careful consideration of the local needs and constraints of the operational context in which the APW is being introduced (section 3.4). Two other strictly interrelated processes are: the *consideration of a reference APW* (section 3.3) and the *development of a policy and safety case* (section 3.5)*.*

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 APW

The previous steps are all needed to take an appropriate decision about the *APW procurement*, either when the product is purchased from an external manufacturer (section 4.2) or when APW 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 APW from scratch or when enhancing an existing APW.

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

2.1.3 Optimising APW

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 APW *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 APW does not meet the established operational requirements.

2.1.4 Operating APW

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

Once APW 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 APW 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 APW 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 APW is not providing the required safety benefits.

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

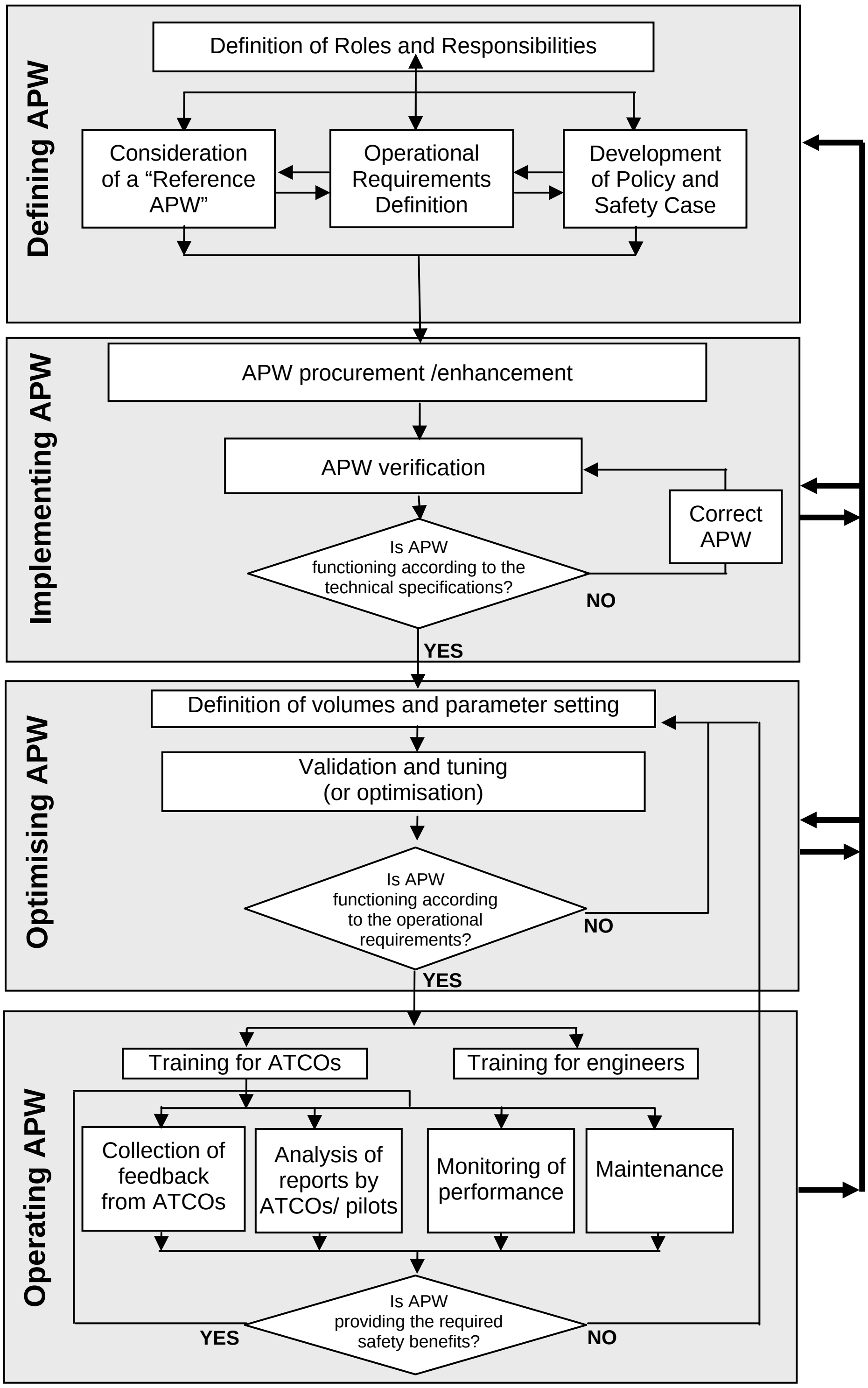

Figure 2-1 The APW Lifecycle

3. DEFINING APW

3.1 Introduction

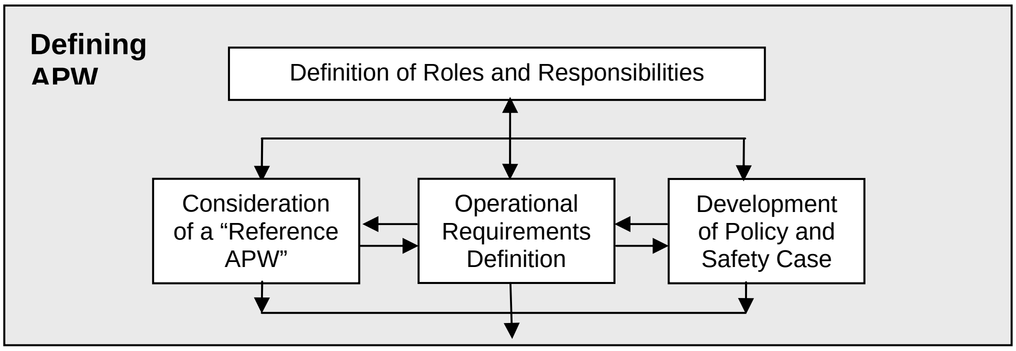

Figure 3-1: First phase of the APW Lifecycle

A preliminary step for defining the APW is making clear and well known the roles and people inside the organisation responsible for the APW. Three parallel processes should then be started: (a) considering a "Reference APW" 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 Specification for Area Proximity Warning requires that:

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

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

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

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

The operational staff should understand where APW is active. Depending on the specific technical capabilities of the system and operational needs, APW could be equally applied to restricted areas of airspace or controlled airspace. Any controllers who could be affected by APW should be consulted when gathering operational requirements.

Finally, an adequate involvement of Safety Management should be ensured both when developing the Policy and Safety Case and when monitoring APW performance. For example, the role of APW 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 the system.

3.3 Consideration of the Reference APW System

The *Reference APW System* is the description of a generic APW implementation, to be used by ANSPs as a reference when setting objectives of their own APW. Rather than being a standard, it is a set of recommended practices aimed at identifying the basic elements of APW and the advantages and disadvantages of various options and parameter settings.

The most essential parts of the reference APW system are summarised in this chapter, to allow an understanding of how APW fits into the ATC system, and the main technical features and options.

For a more in depth description of APW, please refer to chapter two of A*ppendix A: Reference APW System*.

3.3.1 Different Types of APW System

APW systems tend to fall into one of two categories as given below:

1. Those that produce an alert when a civil aircraft is about to enter a restricted area, military aerobatic area or danger area.

2. Those that produce an alert when an aircraft not under ATC has entered controlled airspace.

In principle, APW could be adapted to allow both types of functionality (protection of controlled airspace and restricted areas) to be combined in the same implementation.

However, currently the two types of APW are distinct, and so this document shall where necessary refer to the specific type of system as APW_type1 and APW_type2. APW_type1 protects restricted airspace, APW_type2 protects controlled airspace.

3.3.2 APW in the ATM System Environment

The inputs to and outputs from the reference APW system are best understood in the APW context diagram, shown in Figure 3-2 below:

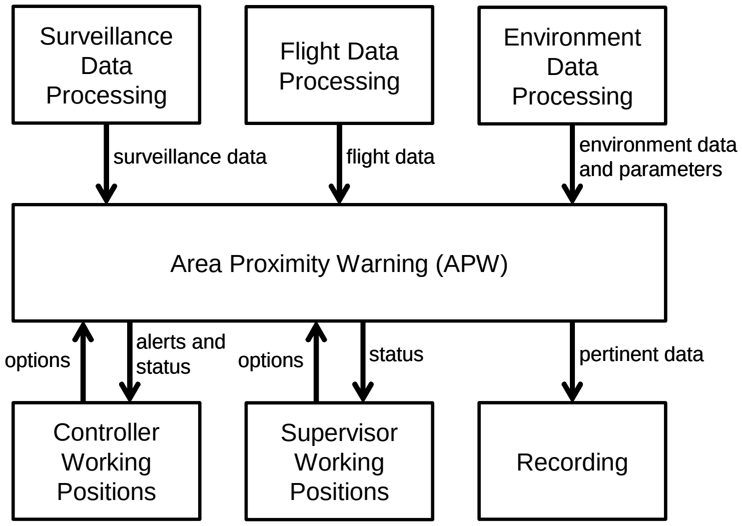

Figure 3-2 APW Context Diagram

As illustrated in the diagram, the reference APW system obtains information from Surveillance Data Processing and Environment Data Processing. As an option, the reference APW system can additionally make use of data from Flight Data Processing.

Surveillance data including tracked pressure altitude information is used to predict hazardous situations. Tracked pressure altitude data (via mode C or mode S) is used to make a prediction in the vertical dimension.

Environment data and parameters are used to define:

- Airspace volumes
- Alerting parameters

Flight data is used to provide additional information, such as:

- Type/category of flight: to determine the eligibility for alert generation
- Concerned sector(s): to address alerts
- Cleared/Block Flight Levels: to increase the relevance of alert generation
- Manually entered Flight Levels: to compensate for missing pressure altitude information

- RVSM status of aircraft to determine appropriate spacing from the volume of airspace

Alerts should be generated at least at a Controller Working Position of the control sector responsible for the infringing aircraft and/or for the airspace subject to unauthorised penetration. Status information regarding the technical availability of APW is to be provided to all Working Positions. Selectable options of APW related to eligibility, configuration and technical availability may be available at Controller and Supervisor Working Positions.

All pertinent APW data should be recorded for offline analysis.

3.3.3 System Tracks Eligible for APW

Most essentially, APW must recognise for which tracks APW alerts are relevant.

Depending on the type of APW (APW_type1 or APW_type2), and upon local requirements, the determination of system track eligibility may be done in a variety of ways.

In APW_type1, it is usual that only tracks that are correlated with a flight plan are processed. The SSR code of the track may also be taken into account to determine whether the track should be processed. In this case an SSR code inhibition list may be part of the off-line APW parameters.

In APW_type2, the SSR code of the track usually determines whether the track should be processed. For these systems the SSR code list of non-controlled codes is part of the off-line APW parameters.

SSR code lists are generally static lists that would be updated when necessary by technical or supervisory staff. On the other hand, some APW implementations allow the controller to selectively inhibit alerts for certain types of flight, or selectively inhibit alerts based on call sign or SSR code.

In the reference APW system, for a track to be eligible for APW processing, the track must:

- Have sufficient track quality.

- Have an SSR code that is selected for processing by APW.

Whether or not an aircraft must be providing pressure altitude in order to be eligible for processing also depends on the type of APW and upon local requirements. For example, it can be appropriate to designate control zones (CTRs), firing ranges or other specific areas in APW, where aircraft without pressure altitude will provoke an APW alert if the aircraft enters the APW area. i.e. the APW volume, without considering the vertical dimension.

3.3.4 APW Parameters

Most APW implementations use a fairly small number of parameters. In the reference APW system, the parameters are:

APWPredictionTime	Prediction time for APW conflict detection	seconds
APWLateralBuffer[FlightType]	Lateral buffer dependant on type of flight	nm
APWVerticalBuffer[FlightType]	Vertical buffer dependant on type of flight	feet
APWUseCFL	Flag to use CFL in APW vertical prediction	Boolean
APWConflictCount	Conflict count for alert confirmation	integer
APWWarningTime	Warning time for APW alert confirmation	seconds

The appropriate values for the parameters will depend very much on the type of APW system. For example, APW_type2 will normally function without any prediction or a buffer (**APWPredictionTime**, **APWLateralBuffer[FlightType]**, **APWVerticalBuffer[FlightType]** all zero).

In APW, the flight-type dependency of the parameters **APWLateralBuffer[FlightType]** and **APWVerticalBuffer[FlightType]** typically relates to IFR and VFR. However, it is conceivable that numerous other flight characteristics could be taken into account (controlled/uncontrolled, civil/military, OAT/GAT etc.) depending on an ANSP's specific requirements.

There is more information on appropriate parameter values in *Appendix A: Reference APW System*.

3.3.5 APW Volumes

The reference APW system allows an indefinite number of APW volumes to be defined. Each volume is defined as a polygon with a floor and ceiling height. In the reference APW system, the floor and ceiling heights may be individually specified in terms of flight levels or altitude for each volume.

For example, the floor of an APW volume could be set to 3000ft, and the ceiling set to FL150. In this case, QNH is used to convert pressure altitude to true altitude before determining whether the aircraft lies above or below the floor.

An example APW volume is shown in plan view in Figure 3-3, below. The APW volume itself is shown by the solid line, and an additional margin (**APWLateralBuffer[FlightType]**) is represented by the dashed line.

The volume is also shown in vertical view in Figure 3-4, with the additional vertical margin (**APWVerticalBuffer[FlightType])** represented by the dashed line.

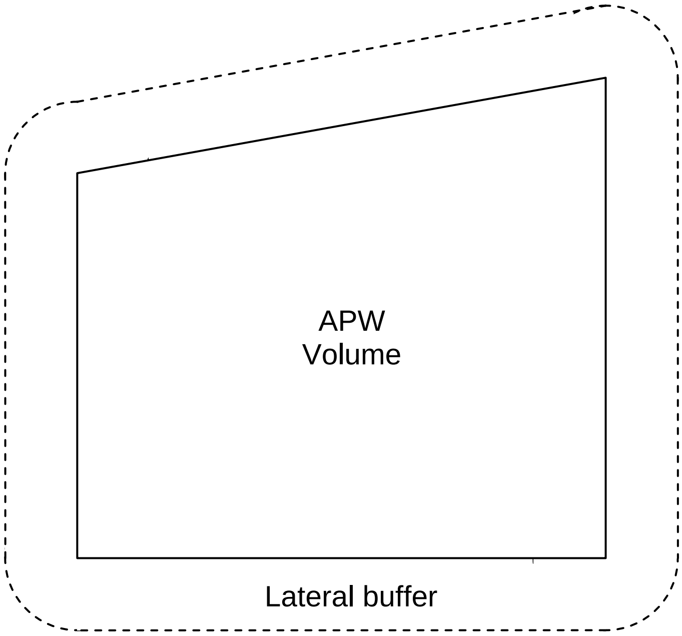

Figure 3-3 Plan View of an APW Volume with a Lateral Buffer

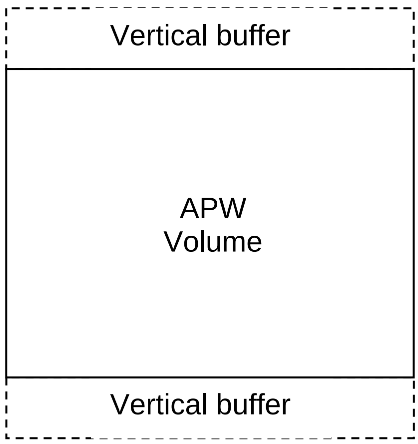

Figure 3-4 Vertical View of an APW Volume with a Vertical Buffer

3.3.6 APW Conflict Detection

For each APW eligible aircraft, the future position of the aircraft is extrapolated forwards from the current track position up to the defined look-ahead time, **APWPredicitonTime**.

In the lateral dimension, the prediction is a straight line extrapolation made using the current track position and velocity.

In the vertical, the prediction is a straight-line extrapolation made using the current pressure altitude, and the vertical rate of the track. Correction for QNH may be made for comparison against an APW height threshold defined in terms of altitude. If the flag **APWUseCFL** is set, then the CFL is taken into account in the vertical prediction.

A conflict is detected if the aircraft is predicted to simultaneously infringe the lateral and vertical limits as defined by the volume itself and by the lateral and vertical buffer parameters (**APWLateralBuffer[FlightType]**, **APWVerticalBuffer[FlightType]**).

Some APW implementations, particularly for military ATC, also provide alert when an aircraft is about to leave an APW volume. In this case APW would warn the military controller that an aircraft is about to proceed into civil airspace.

3.3.7 Alert Confirmation

The alert confirmation stage in APW has a number of objectives:

- To test if an APW volume is currently infringed and an alert is required immediately
- To suppress an alert which might be caused by spurious track data
- To suppress an alert which might be caused by a transitory situation
- To test whether an alert is required on this cycle, or should be delayed, with the hope that the situation will be resolved before an alert is necessary.
- To continue an alert when there are temporary perturbations in the track data.

Essentially, the alert confirmation stage determines whether to issue an alert based upon the number of conflict “hits” from previous track cycles and the time of violation (i.e. the remaining time until the APW volume is penetrated, adding on any lateral and vertical buffer).

Although the precise algorithm differs between each system, essentially the number of consecutive “hits” is compared with the parameter

APWConflictCount, and the time of violation is compared with the parameter **APWWarningTime**.

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 APW 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 APW, 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., APW volumes, types of alert inhibition, etc)
2. system capacities (e.g. number of APW volumes 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 APW can be a challenge, especially for individuals who have had no previous experience in either APW 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, but to refrain from analysing them closely. 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 APW)*
- Product research *(product surveys, web searches, ANSP feedback)*
- Use of guidance material *(Reference APW 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 APW 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 experts in the process. The experience of operational staff should cover the entire airspace in which APW will be active. Important input into the requirements capture will also come from a number of technical experts who should have knowledge of APW, 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 APW the requirements will be frozen.

Each requirement should be:

- Correct
- Unambiguous
- Complete
- Consistent
- Ranked for importance
- Verifiable
- Atomic
- Modifiable
- Traceable

3.4.3.1 *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.

3.4.3.2 *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.

3.4.3.3 *Complete*

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

3.4.3.4 *Consistent*

Each requirement should neither contradict nor repeat any other requirement.

3.4.3.5 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)

3.4.3.6 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”.

3.4.3.7 Atomic

There should be only one action or concept per statement.

3.4.3.8 Modifiable

Avoid duplication of requirements and structure the operational requirements document to be easily modifiable.

3.4.3.9 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 APW Requirements Checklist

Table 3-1 below outlines a number of questions that an ANSP will find useful to address in order to help define the requirements for APW. 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 APW manufacturers.

1. Current and Future Operational Environment 1.1 Within which classifications/types of airspace will APW be adopted? Airspace Classification (e.g. Class A – G), controlled airspace, military airspace, danger areas, prohibited areas, restricted areas, glider areas, segregated areas. 1.2 What aerial activity is conducted in and close to the APW airspace? Straight flight, vertical transitions, turns, aerobatics, military operations, low speed, high energy manoeuvres, gliders. 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? Busy periods, traffic laterally very close to APW volumes, traffic just below or above the volumes? 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 proedures? Standing agreements? Silent coordination?
2. Current and Future ATM System Components 2.1 Flight Data Processing System Correlation used for APW eligibility? Flight plans available over area of interest? APW function in FDPS failure modes? 2.2 Data Recording System Recording of tracks and alerts? Recording of internal APW values? Sufficient to allow verification of APW, or alert analysis? 2.3 Other Data Inputs QNH, Temperature, NOTAM

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? Coasting tracks? Transponder faults? Reflections?

3.3 Data Content

Track age? Track quality? Height precision? Coasting Indicator? SFL?

4. Track Eligibility, APW 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 APW volumes

Required shape of APW volumes? Polygons? Curved boundaries?

APW volume activation (on and off) either manually or automatically, timetables, NOTAM messages?

4.3 Parameters

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

Parameter ranges sufficient for optimisation?

5. APW System Features (see Reference APW System for more information) 5.1 Conflict Detection Mechanisms (linear prediction, current position etc) 5.2 Use of CFL/SFL 5.3 Alert Confirmation Stage? (Time of Violation Tests, Conflict Counts, Conflict Probability) 5.4 Conflict Alert Message Supports multi-level alarms? Contains pertinent data (TOV, Volume I.D.)?
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 APW alert)? 6.6 Alert inhibition (the suppression of one or more tracks from APW processing)? 6.7 Display of APW status (to controller(s), supervisor)?
7. Tools and Support 7.1 Tools Data recording and playback? Display of internal APW values? APW analysis and tuning tools? Plot/track/flight generator to create test scenarios? Other display tools for APW definitions, encounters or hot spots? 7.2 After Sale Support Support for set up and optimisation? Training / documentation for technical staff and controllers?

Table 3-1 APW Requirements Checklist

3.5 Development of a Policy and a Safety Case

3.5.1 Development of a Policy

The EUROCONTROL Specification for Area Proximity Warning requires that:

The ANSP shall have a formal policy on the use of APW consistent with the operational concept and SMS applied.

The policy should be consistent with the following generic policy statements:

> **APW IS A GROUND-BASED SAFETY NET; ITS SOLE PURPOSE IS TO ENHANCE SAFETY AND ITS PRESENCE IS IGNORED WHEN CALCULATING SECTOR CAPACITY.**
>
> **APW IS DESIGNED, CONFIGURED AND USED TO MAKE A SIGNIFICANT POSITIVE CONTRIBUTION TO PREVENTION OF ACCIDENTS ARISING FROM UNAUTHORISED PENETRATION OF AN AIRSPACE VOLUME.**

APW 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 the situation.

The policy should be developed in collaboration with controllers who have experience of using APW 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 APW is to be used. Consequently, these statements should steer much of the APW 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 APW is available in the following three documents:

Appendix B-1: Initial Safety Argument for APW System

Appendix B-2: Generic Safety Plan for APW Implementation

Appendix B-3: Outline Safety Case for APW System

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.

Appendix B-1: Initial Safety Argument for APW System - Ideally, produced during the definition phase of a project to introduce a change to the ATM system e.g. to introduce APW. The process of developing and acquiring the necessary assurance is considerably enhanced if the safety arguments are set out clearly from the outset.

Appendix B-2: Generic Safety Plan for APW 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.

Finally, *appendix B-3: Outline Safety Case for APW 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 APW

4.1 Introduction

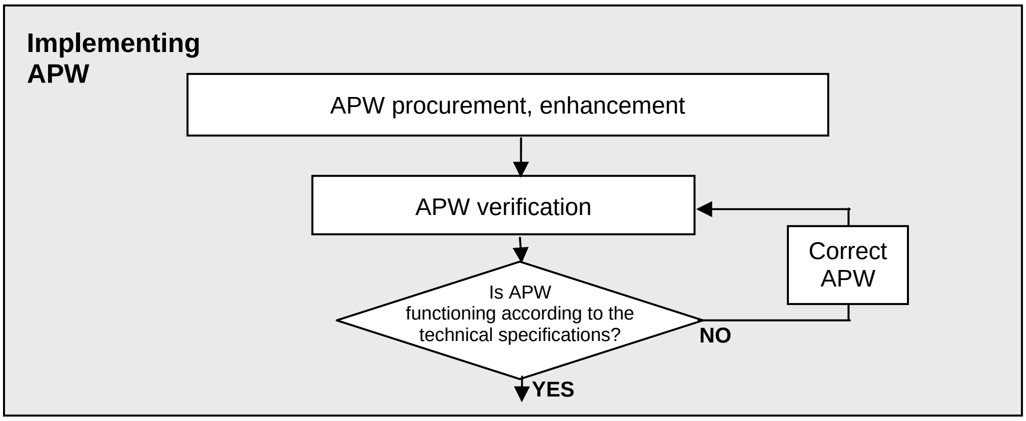

Figure 4-1: Phase 2 of the APW Lifecycle

ANSPs will normally choose between two alternative options when covering this lifecycle phase: (a) purchasing an APW 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 the two Appendixes referenced below.

Appendix A: Reference APW System describes a generic or reference APW system, with a number of optional features. This document can provide useful information for those making decisions related to system procurement or enhancement.

A cost framework is provided in *appendix C: Cost Framework for the standardisation of APW*. This gives guidance to the cost of implementing or enhancing APW to meet the requirements prescribed in the EUROCONTROL Specification for Area Proximity Warning

4.2 Procurement of APW

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

Manufacturers of APW 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.

APW, 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 APW is appropriate.

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

The purchaser should review the APW 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 APW 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 APW 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 4-1 below:

What is the extent of the airspace to be covered by APW?
What type of airspace is the APW system to protect (controlled airspace, restricted areas)?
What types of flight are eligible for APW processing?
What are the main features of APW, and are they in accordance with aircraft behaviour, tracker behaviour and local operational procedures? (Perhaps think about whether aircraft will be legitimately flying close to the APW volumes, tracker characteristics etc)
What SDP (tracking) data will be provided to APW, and is it of sufficient coverage and quality?
What other data will be supplied to APW? Flight plan data? Data input by the controller?
How will APW alerts be presented to the controller?
Does the facility exist for the controller to be able to manually inhibit alerts?
How are parameters set?
How are APW volumes defined in the operational system?
Is the maximum number of APW volumes sufficient for current and future needs?

Can APW volumes be dynamically activated / deactivated?
Are other APW capacities sufficient for both current and future needs?
Do the parameters (or range of values) allow APW to be optimised for the airspace?
What APW analysis tools are provided?
Is the APW capable of recording its internal values, and are they sufficient for testing?
Who will test APW? And how will it be tested?

Table 4-1 Example List of Relevant Questions

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.

APW 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 APW.

4.3 Enhancement of an Existing APW

4.3.1 Introduction

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

The need to enhance APW 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:

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

As well as improving alerting performance, APW 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 APW is normally less expensive than buying a new one from scratch. In any case, a new APW may not necessarily solve the original problem(s). Furthermore, the ANSP is generally familiar with how their APW operates, and can often foresee how APW 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 APW, or draw on external technical expertise.

A practical example of APW enhancement for military operational purposes is given in *appendix D-1: Enhancement of APW for ATCC Semmerzake.*

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 APW 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 APW model is an ideal instrument for testing many proposed improvements to APW, 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 APW running on a non-operational partition of the ATC system.

When adding new logic to APW, 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 APW

The most important step is to identify and fully understand the nature of any deficiencies with APW. Figure 4-2, below, is an idealised troubleshooting process that shows the steps that should be taken when trying to solve problems related to APW performance. The feedback loop in the process ensures that if APW 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 APW parameter settings.

It is not always necessary for APW to be technically enhanced. Many problems can be overcome or reduced by modifying the shapes of the APW volumes. Furthermore, making parameter or volume 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. In the event that specific SSR codes are assigned to flights that are intentionally close to the APW volume(s), careful consideration should be given to how such codes should be treated in the APW 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 APW. 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 APW processing).
- Check that APW is not using data that is too aged.

- If APW is using smoothed tracks, make sure these tracks are fit for APW. If the tracking quality is too poor, it may be better for APW to use raw plot data instead.

- Make sure that APW gives priority to the most critical alerts – i.e. APW alerts immediately if the aircraft is currently infringing an APW volume.

Certain problems, such as erroneous tracks (due to tracking blunders, radar reflections or erroneous transponders) are not usually solved by tuning the APW 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 APW system. Instead, problems with the tracks introduced to APW should, if possible, be solved within the wider surveillance system.

Furthermore, APW 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 APW may be made, for example, by the introduction of new algorithms.

ANSPs should select enhancements that are in accordance with how aircraft behave in the airspace and local operational procedures. APW may also be improved through the use of aircraft derived data. For example, the use of CFL and SFL is best considered only if the CFL is input as part of normal ATC procedures of if SFL is available from Mode S Enhanced Surveillance.

The ANSP should review the overall effect of any changes to APW on alerting performance, and should consider whether the system needs re-tuning to redress the balance between warning time and nuisance alert rate.

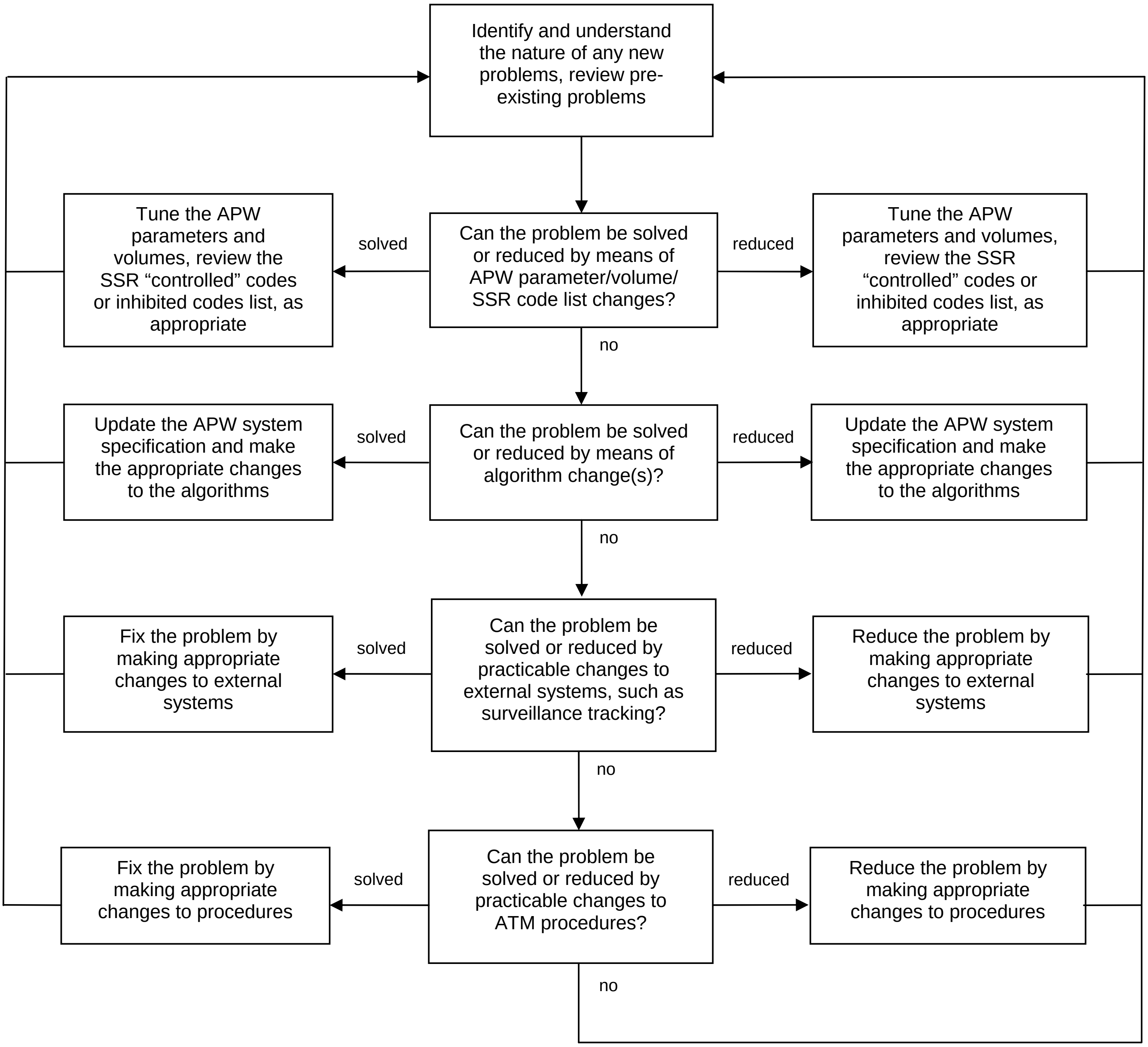

Figure 4-2 Idealised Troubleshooting Chart for APW

4.5 HMI Options for APW

4.5.1 Introduction

Controller's displays vary between the ECAC states, and likewise so does the presentation of APW alerts, and APW 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 is should be clear and unambiguous. Even if APW 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 Specification for Area Proximity Warning requires that:

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

It continues:

An audible element ***should*** be included to improve the systems ability to draw the controller's attention to the alert. 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 ("APW" or "A") 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 APW 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 Specification for Area Proximity Warning:

APW-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 APW Status Information

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

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

4.6 APW Verification

4.6.1 Verification Methods

The aim of verification is to check that APW 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 APW data are described in detail in chapter 5 of *appendix A: Reference APW System*.

It is normally the responsibility of the manufacturer to make sure that APW 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 APW Model

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

For an accurate APW 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 APW.

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

- Produce or acquire a detailed and accurate specification of the APW algorithms.

- Produce the operational APW – the operational APW 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 APW is under production, other engineers should produce an APW model to the same specification. The APW model should be made capable of producing the same trace messages.

- Design and produce test scenarios to exercise all aspects of the APW logic. All essential information, such as parameter values APW volumes and QNH must also be specified as part of each test. A number of example test scenarios are given in *appendix A: Reference APW System*.

  (Note that for test scenarios, the APW volumes, 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 APW logic are provoked. For some tests it may be convenient to use extreme parameter values).

- Input the test scenarios into the operational APW, recording the surveillance data used by APW, the alerts and trace messages.

- Input the same test scenarios into the APW model, recording the alerts and trace messages. To ensure the surveillance data are identical to those used by the operational APW, it may be necessary to use the surveillance data recorded from the operational APW 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 APW is incorrect it will have to be fixed and the tests rerun. Note that it is also possible that a difference between APW 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 APW, 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 APW model, recording the alerts and trace messages. Again, to ensure the surveillance data are identical to those used by the operational APW, it may be necessary to use the surveillance data recorded from the operational APW in the previous step

- Compare the alerts and trace messages from the operational APW and the model, resolving any differences.

- Repeat the previous three steps until all the differences have been resolved.

4.6.3 Verification without an APW Model

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

Without an APW model, one approach to verification is:

- Produce or acquire a detailed and accurate specification of the APW algorithms.

- Produce the operational APW – 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 APW logic. The APW volumes, parameter values and QNH required must also be specified as part of each test. (Note that 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 APW, 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 APW

5.1 Introduction

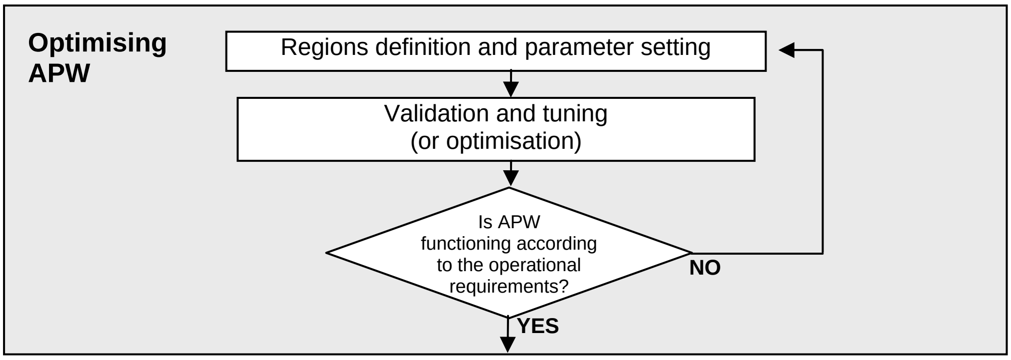

Figure 5-1: Phase 3 of the APW Lifecycle

The objective of APW optimisation is tuning the APW volumes and parameters to meet the requirements laid out in the EUROCONTROL Specification for Area Proximity Warning:

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

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

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

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

APW-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.

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

Meeting such requirements also means optimising the APW 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 APW in order to keep APW optimised for the ever changing operational environment.

Essential elements of this process are: (a) the Definition of the APW 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 *appendix A: Reference APW System*, with suggestions on how to define parameters.

The material includes guidance to parameter optimisation for the reference APW 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 APW, given certain surveillance data as input.

2. The capability to alter the APW volumes and parameter settings, so the results of various configurations can be compared.

The method presented in *appendix A* is highly recommended because it includes quantitative measures of APW 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 APW 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

The diagram below shows the tools and data files that are appropriate for APW parameter optimisation. Tools or processes are indicated in bold type, files are shown in normal type.

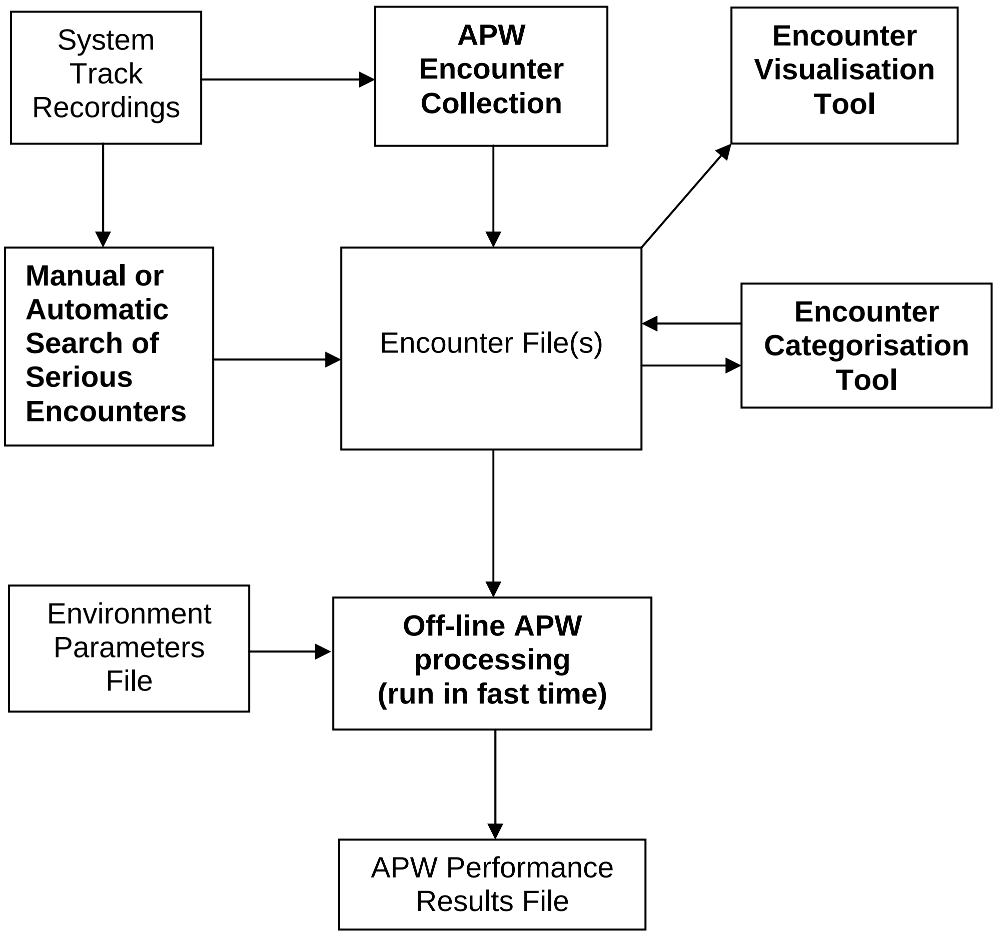

Figure 5-2 Tools and Files Required for Parameter Optimisation

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 APW 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 APW.

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:

Category 1	ALERT NECESSARY – the situation involved a serious infringement of the protected airspace (APW volume) or avoided such an infringement by a late manoeuvre.
Category 2	ALERT DESIRABLE – although there was no serious infringement, an alert would have been useful in drawing the attention of the controller to the situation. Most of these situations can be resolved by conventional ATC instructions, without resorting to emergency manoeuvres.
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 infringement of an APW volume 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 APW.

Table 5-1 Definition of Encounter Categories

The encounter categorisation process needs to be done before inputting the encounter file into the APW 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. A 3-D visualisation tool could be used. Otherwise, software that generates a printed diagram showing the situation in lateral and vertical view may be used. The diagram should also show pertinent data such as the APW volumes. 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 APW alert is desirable for particular borderline situations.

5.3.6 The Off-Line APW processing

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

The off-line APW process must be functionally identical to the operational system. Also, the process should be able to run in fast time, so that several weeks worth 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 APW process will record various data, such as described in *appendix A*.

5.3.7 APW Performance Results

The APW 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 relevant APW volume

5.3.8 Requirements for APW 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 APW performance are listed in Table 5-2, below:

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

Table 5-2 Possible APW Performance Requirements

In order to maximise performance, repeated runs with different APW adaptations are generally required. Guidance for parameter settings is given in *appendix A*.

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 APW 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 APW 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 APW Systems

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

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

Whereas a model can run in fast time, a test APW will be limited to (more or less) real time. To save manual effort, all the encounters may be best injected into APW 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 APW 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 APW. 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 APW volume 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 APW 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 APW alert is depicted. The data used to show the alert positions should be taken from an extensive period of real data (recorded APW alerts), or alerts from an off line APW model.

5.4.5 Warning Time Measures for APW

Appendix A: reference APW System describes the calculation of warning time for measuring APW 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 APW model or the test APW). 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 APW

6.1 Introduction

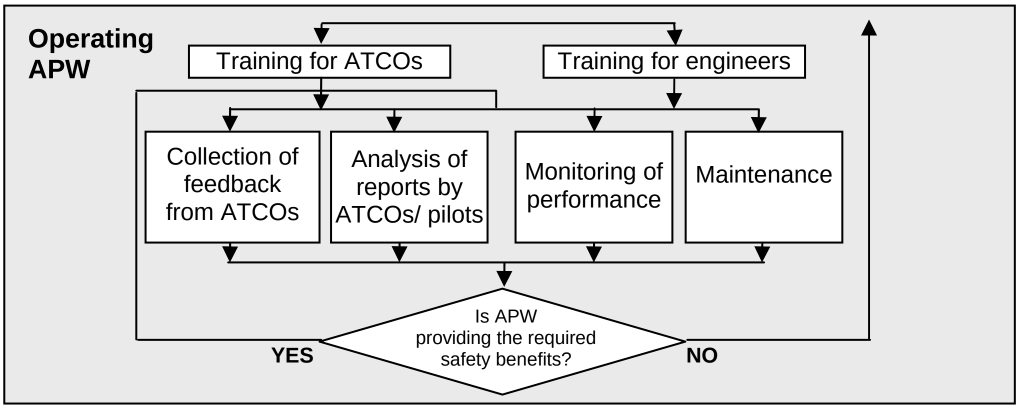

Figure 6-1: Phase 4 of the APW Lifecycle

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

6.2 Training for ATCOs

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

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

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

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

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

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

A number of tools, such as ATC test partitions, ATC simulators, APW 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 Skill Development for Engineers / Operational Analysts

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

Most importantly, engineers should understand how their APW works; requiring that they become familiar with the APW 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 APW. 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 APW algorithms.

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

It is a useful exercise to collect and analyse all APW 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 APW parameters affect performance.

It is a useful exercise to compare the specific APW system with the reference APW System in *appendix A*, and furthermore *appendix A* provides detailed advice on parameter setting, and optimisation.

6.4 Analysis of Pilot/ATCO reports

It is good practice to analyse the performance of APW 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 APW algorithms.

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

6.5 Monitoring of APW Performance

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

6.6 Maintenance

APW SSR code files should be updated to reflect changes in SSR code allocations, otherwise APW 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 APW performance improves rather than degrades following changes to the air traffic environment.

Note: Appendices are contained in separate documents.

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