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EUROCONTROL Guidance Material for Approach Path Monitor

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Abstract		
This document contains comprehensive guidance material to assist in implementing the EUROCONTROL Specification for Approach Path Monitor. It covers the full APM lifecycle, including definition of objectives; implementation or change; tuning and validation; as well as operating and monitoring.		
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Contact Person(s)	**Tel**	**Unit**
Ben Bakker	+32 2 72 91346	CND/COE/AT/AO

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EUROCONTROL Agency, Library Documentation and Archives (ALDA)
EUROCONTROL Headquarters (50.703)
96 Rue de la Fusée
B-1130 BRUSSELS

Tel: +32 (0)2 729 11 52
E-mail: publications@eurocontrol.int

DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME AND SIGNATURE	DATE
Technical Manager	Ben Bakker	19-5-2009
Head of ATC Operations and Systems Unit	Martin Griffin	19-5-2009
Deputy Director Network Development	Alex Hendriks	19-5-2009

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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 Approach Path Monitor. Specifically, the document contains guidance related to the APM lifecycle, including:

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

1. INTRODUCTION

1.1 Purpose of this Document

APM 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 during final approach.

The European Convergence and Implementation Plan (ECIP) contains an Objective (ATC02.7) for ECAC-wide standardisation of APM in accordance with the EUROCONTROL Specification for Approach Path Monitor.

The EUROCONTROL Specification for Approach Path Monitor 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 staff.

The purpose of this document is to provide practical guidance material to assist in implementing the EUROCONTROL Specification for Approach Path Monitor. The guidance material covers the full APM lifecycle.

1.2 Structure of this Document

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

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

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

Chapter 5 addresses APM System tuning and validation aspects.

Chapter 6 highlights APM 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 APM System	Detailed technical explanation of typical implementation details of APM 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 APM safety assurance work in a particular local context.
Appendix B-1: Initial Safety Argument for APM 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 APM 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 APM 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 APM	Assists in identifying potential financial implications of standardisation of APM in compliance with the EUROCONTROL Specification for Approach Path Monitor.
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 APM for Geneva	Identifies potential alternative solutions for APM for Geneva and other airports.

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.
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 aircraft proximity to terrain or obstacles during final approach.
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).
final approach	That part of an instrument approach procedure which commences at the specified final approach fix or point, or where such a fix or point is not specified, a) at the end of the last procedure turn, base turn or inbound turn of a racetrack procedure, if specified; or b) at the point of interception of the last track specified in the approach procedure; and ends at a point in the vicinity of an aerodrome from which: 1) a landing can be made; or 2) a missed approach procedure is initiated.

flight level [Doc 4444]	A surface of constant atmospheric pressure which is related to a specific pressure datum, 1 013.2 hectopascals (hPa), and is separated from other such surfaces by specific pressure intervals. *Note 1.– A pressure type altimeter calibrated in accordance with the Standard Atmosphere:* *a. when set to a QNH altimeter setting, will indicate altitude;* *b. when set QFE altimeter setting, will indicate height above the QFE reference datum;* *c. when set to a pressure of 1 013.2 hPa, may be used to indicate flight levels.* *Note 2.– The terms "height" and "altitude", used in Note 1 above, indicate altimetric rather than geometric heights and altitude.*
ground-based safety net [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.
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.*

1.5 Abbreviations and Acronyms

ANSP	Air Navigation Service Provider
APM	Approach Path Monitoring
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATS	Air Traffic Service
CFIT	Controlled Flight Into Terrain
EATMN	European Air Traffic Management Network
EC	European Commission
ECAC	European Civil Aviation Conference
ECIP	European Convergence and Implementation Plan
(E)GPWS	(Enhanced) Ground Proximity Warning System
ESARR	EUROCONTROL Safety Regulatory Requirement
FAF	Final approach Fix
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
MSAW	Minimum Safe Altitude Warning *Note.– Not to be confused with MSA (Minimum Sector Altitude).*
MSL	Mean Sea Level
OAT	Operational Air Traffic
QFE	Atmospheric pressure at aerodrome elevation *(or at runway threshold)*
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
SAT	Site Acceptance Test
SES	Single European Sky
SRC	Safety Regulatory Commission
SSR	Secondary Surveillance Radar
VFR	Visual Flight Rules

1.6 Relevant Material from the EUROCONTROL Specification

The EUROCONTROL Specification for Approach Path Monitor should be referred to for a description of the APM concept of operations.

Furthermore, chapter four of the EUROCONTROL Specification for Approach Path Monitor contains specific requirements, which are referred to in relevant sections of this document.

2. THE APM LIFECYCLE

2.1 Overview of the APM Lifecycle

The APM lifecycle represents an ideal process followed by ANSPs to ensure a solid and consistent development of APM 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 APM

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 APM. 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 APM, based on a careful consideration of the local needs and constraints of the operational context in which the APM is being introduced (section 3.5). Other two strictly interrelated processes are: the *consideration of a reference APM* (section 3.3) and the *development of a policy and safety case* (section 3.7.5.1).

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

2.1.2 Implementing APM

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

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

2.1.3 Optimising APM

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 APM 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 APM does not meet the established operational requirements.

2.1.4 Operating APM

When APM is deemed validated or optimised, adequate *training* is provided to both ATCOs (section 6) and engineers (section 6.3).

Once APM 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 APM performance (section 6.5)
- Maintenance (section 6.6)

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

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

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

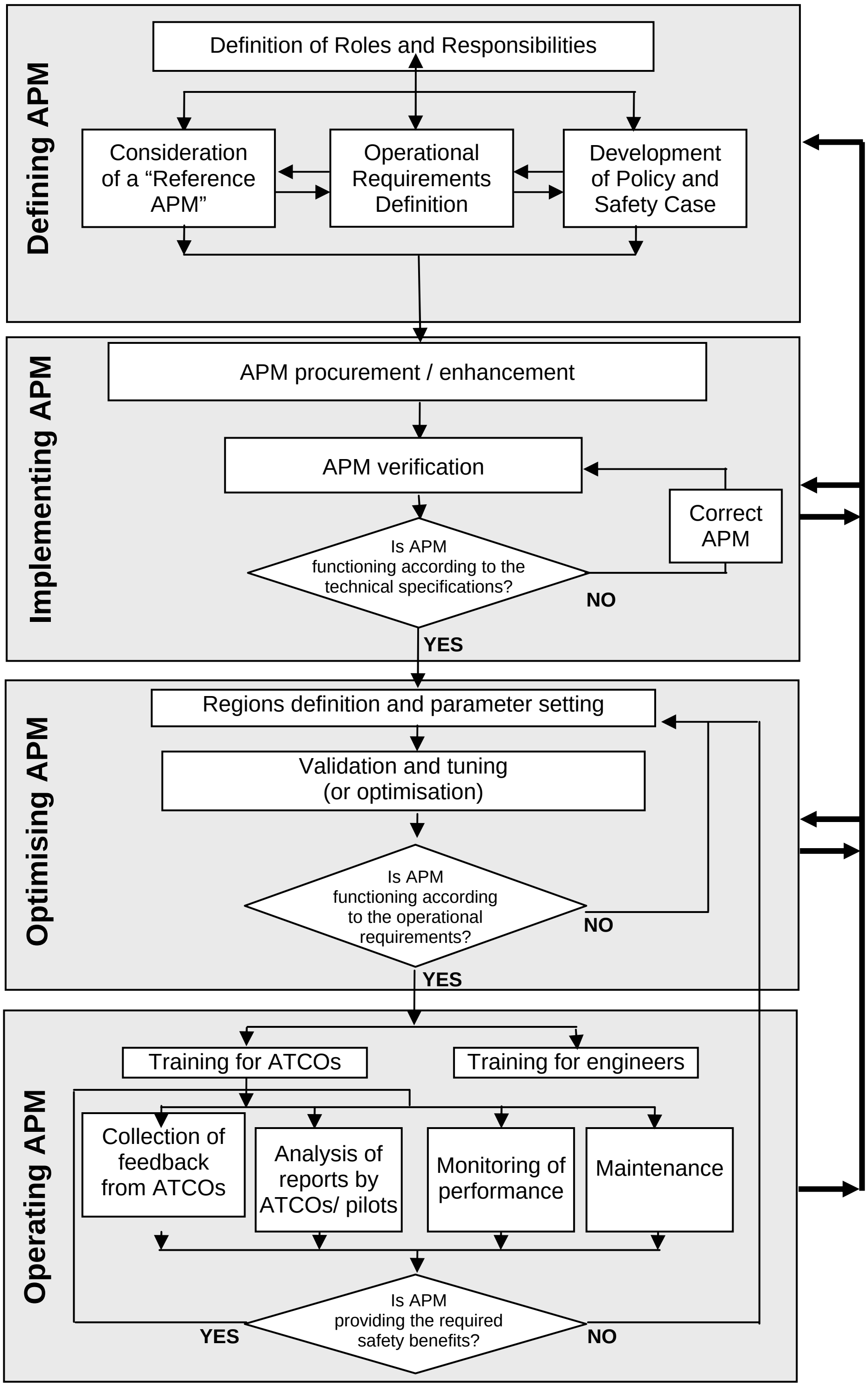

Figure 2-1 The APM Lifecycle

3. DEFINING APM

3.1 Introduction

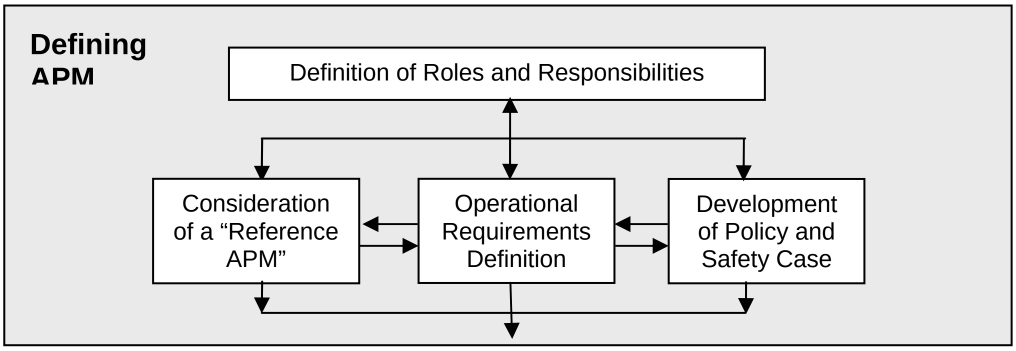

Figure 3-1: First phase of the APM Lifecycle

A preliminary step for defining the APM is making clear and well known the roles and people inside the organisation responsible for the APM. Three parallel processes should then be started: (a) considering a "Reference APM" 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 Approach Path Monitor requires that:

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

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

Management of APM can be addressed in different ways, according to the specific characteristics and constraints of the ANSP. Nevertheless, through various phases of the APM lifecycle, a mix of different staff will be required, including technical, operational and safety specialists. Despite the fact that developing an APM may appear to be a purely technical exercise, it is of paramount importance that APM 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 APM is active. Strictly, APM is applied for aircraft on final approach. However, APM need not be restricted to large commercial airports; it could equally be applied to regional airports, as well as civil and military airfields. Approach controllers and any others who could be affected by APM 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 APM performance. For example, the role of APM 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 during 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 APM System

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

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

3.3.1 APM in the ATM System Environment

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

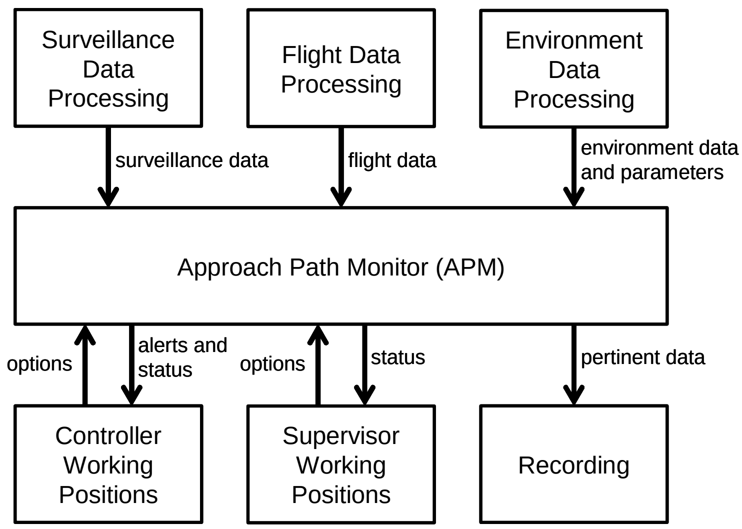

Figure 3-2 APM Context Diagram

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

Surveillance data including tracked pressure altitude is used to detect hazardous situations.

Environment data and parameters are used to define:

- Terrain and obstacle data
- Alerting parameters
- Additional items (QNH, temperature, etc.)

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

- Type/category of flight: to determine the eligibility for alert generation and possibly also the parameters applied
- Concerned sector(s): to address alerts

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

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

3.4 System Tracks Eligible for APM

Most essentially, APM must recognise which tracks belong to aircraft under responsibility of the control centre, and for which tracks APM alerts are relevant.

Depending on local requirements, the determination of system track eligibility can be done in a variety of ways. Often only tracks that are correlated with a flight plan are processed. Alternatively, the SSR code of the track may be used to determine whether the track should be processed.

An APM inhibition list is often part of the off-line APM parameters. In this respect it is a static list that would be updated when necessary by technical or supervisory staff. On the other hand, APM provides the possibility to inhibit alerts for specific runways and for individual flights.

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

- Have a valid pressure altitude flight level.

- Be under the responsibility of the ATC centre.
- Have sufficient track quality.
- Have an SSR code that is not on an APM inhibition list.

3.5 APM Parameters

In many cases APM employs a limited number of parameters. This means almost all the tuning is done by careful design of the Approach Path Definitions (Section 3.6).

Furthermore, in many cases APM detects only deviations below the glide slope, whereas in some cases APM also detects lateral deviations or deviations above the glide slope.

In the reference APM system, the various detection mechanisms are activated by just three parameters:

APMAcitvateBelowGlideSlope	Activate Below Glide Slope Alerts	Boolean
APMAcitvateAboveGlideSlope	Activate Above Glide Slope Alerts	Boolean
APMAcitvateLateralDeviation	Activate Lateral Deviation Alerts	Boolean

3.6 Approach Path Definitions and Conflict Detection

The reference APM system allows an indefinite number of APM definitions, one for each runway of operational interest. Each approach path definition has a name, identifying the airport and runway, and parameters that define a broadly funnel-shaped volume describing the limits of the nominal final approach path.

If arrival airport information is available from the flight plan, the reference APM system will make use of this information and will only test aircraft against the relevant approach path definition. Otherwise each aircraft track is tested against all the defined approach paths.

In reality, the exact shape of the approach path volume differs between the various APM systems. Nevertheless, the shape of the approach path definition for the reference APM, described below, is fairly typical.

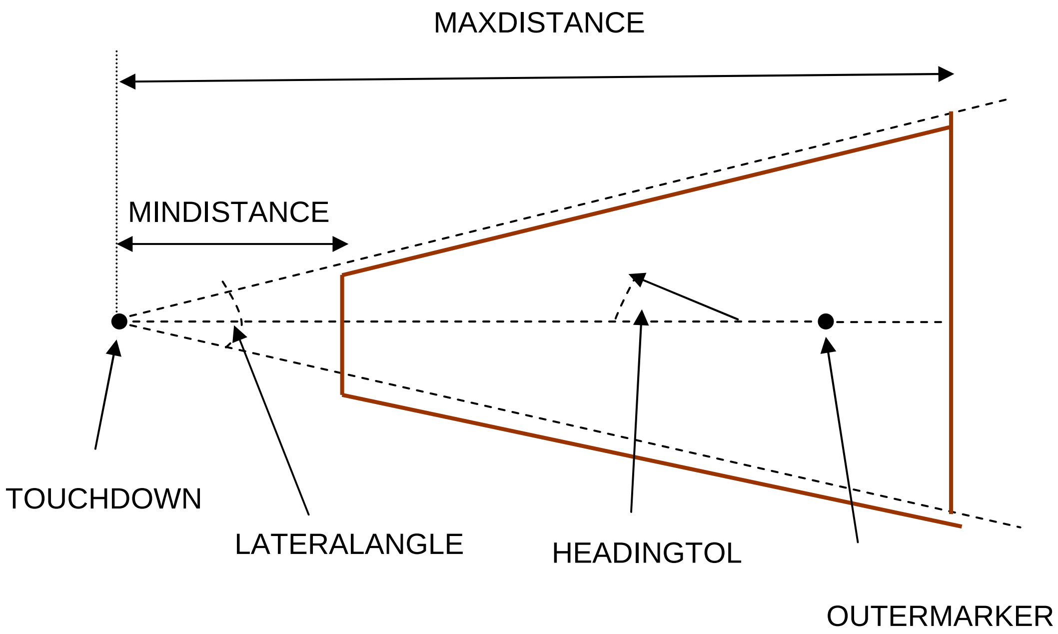

Figure 3-3 Plan View of APM Approach Path Definition

The TOUCHDOWN point and the OUTERMARKER point between them define the expected touchdown point for aircraft landing on the particular runway and the orientation of the approach path.

LATERALANGLE defines the angular extent of the lateral area, and MINDISTANCE and MAXDISTANCE complete the lateral area definition.

Aircraft are not processed by APM if they are less than MINDISTANCE or more than MAXDISTANCE from the runway touchdown.

If the aircraft is within the lateral area and the heading of the aircraft is within HEADINGTOL of the nominal approach path, then the aircraft is deemed to be on final approach. It is then subject to vertical and lateral APM alerts as described further.

If an aircraft previously detected on final approach exits the lateral area shown above, then the aircraft is deemed to have deviated from the ideal lateral approach path. In this case, if the parameter **APMActivateLateralDeviation** is set, then a lateral deviation alert is generated for display to the controller.

If the aircraft is on the lateral final approach path (aircraft heading within HEADINGTOL of runway approach) then the current vertical position is considered relative to the approach path shape, shown below:

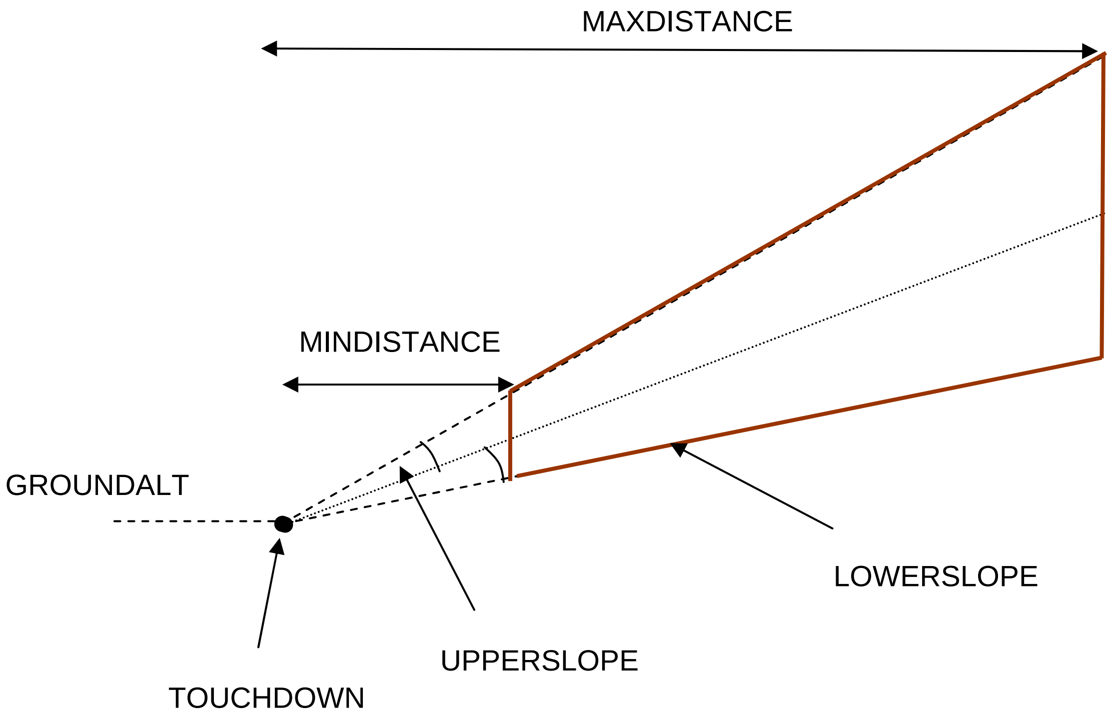

Figure 3-4 Altitude View of APM Approach Path Definition

The vertical section of the volume is defined by GROUNDALT, TOUCHDOWN, LOWERSLOPE, UPPERSLOPE, MINDISTANCE and MAXDISTANCE as shown in the altitude view diagram.

If **APMActivateBelowGlideSlope** is set and the aircraft's current vertical position is below LOWERSLOPE then a below glide slope alert is generated for display to the controller.

If **APMActivateAboveGlideSlope** is set and the aircraft's current vertical position is above UPPERSLOPE then an above glide slope alert is generated for display to the controller.

Note that the vertical position of the aircraft is based on the derived pressure altitude, corrected for the local QNH. If local air temperature is available, this may be used to further refine the altitude measurement.

3.7 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 APM 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 APM, 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. APM approach path definition, types of alert, alert inhibition, etc)
2. system capacities (e.g. number of APM approach paths 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 APM can be a challenge, especially for individuals who have had no previous experience in either APM 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.

3.7.1 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 APM)*
- Product research *(product surveys, web searches, ANSP feedback)*
- Use of guidance material *(Reference APM 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 3.7.4)*
- Brainstorming techniques are particularly suited to where requirements are considered vague *(Best done 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 APM 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 both operational, technical and safety experts in the process. The experience of operational staff should cover the entire airspace in which APM will be active. Important input into the requirements capture will also come from a number of technical experts who should have knowledge of APM, 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.

3.7.2 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.

3.7.3 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 the 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 APM the requirements will be frozen.

Each requirement should be:

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

3.7.3.1 *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.

3.7.3.2 *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.

3.7.3.3 *Complete*

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

3.7.3.4 *Consistent*

Each requirement should neither contradict nor repeat any other requirement.

3.7.3.5 *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)

3.7.3.6 *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”.

3.7.3.7 *Atomic*

There should be only one action or concept per statement.

3.7.3.8 *Modifiable*

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

3.7.3.9 *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.

3.7.4 The APM 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 APM. 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 APM manufacturers.

1. Current and Future Operational Environment

1.1 For what types of flight will the APM system need to be configured?

Visual approach, instrument approach (precision / non-precision)

1.2 What types of flights are of concern?

Civil, Military, General Aviation, IFR, VFR, GAT, OAT

1.3 What is the nature of the traffic?

Busy periods, parallel runways, occasional use runways (e.g. grass) unusual arrival routes?

2. Current and Future ATM System Components

2.1 Flight Data Processing System

Correlation used for APM eligibility? Flight plans available over area of interest?

APM function in FDPS failure modes? Destination airport/runway in flight plan?

2.2 Data Recording System

Recording of tracks and alerts? Recording of internal APM values?

Sufficient to allow verification of APM, 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? Coasting tracks? Transponder faults? Reflections?

3.3 Data Content

Track age? Track quality? Height precision? Coasting indicator?

4. Track Eligibility, APM Definitions and Parameters 4.1 Eligibility Eligibility based on tracks correlated to a flight plan and/or SSR code lists? Use of track quality? Track age? Use of destination data (airport/runway)? Are some tracks/flights to be inhibited (manually or automatically)? 4.2 APM Approach Path Definition Precise APM approach path definitions – straight or angular funnel? Shaped to allow for aircraft joining glide slope at 2500ft or 3000ft? Shaped to take account of parallel runways? Cut-off point before touchdown (where APM is inhibited)? Approach path activation (on and off) either manually or automatically? 4.3 Parameters Which parameters must be tuneable (e.g. sensitivity, false alerts)? Parameter ranges sufficient for optimisation?
5. APM Features (see Reference APM System for more information) 5.1 Conflict Detection Mechanisms Below glide slope, above glide slope, lateral deviation 5.2 Conflict Alert Message Supports alarms of different types (above/below etc)? Contains pertinent data (distance/time to runway threshold, vertical/lateral deviation distance)?

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 multiple types of alarms? 6.5 Alert acknowledgement (the suppression of a current APM alert)? 6.6 Alert inhibition (the suppression of one or more tracks from APM processing)? 6.7 Display of APM status (to controller(s), supervisor)?
7. Tools and Support 7.1 Tools Data recording and playback? Display of internal APM values? APM analysis and tuning tools? Plot/track/flight generator to create test scenarios? Other display tools for APM 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 APM Requirements Checklist

3.7.5 Specific Issues

3.7.5.1 The use of temperature in APM

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 1000ft (after QNH correction), would in fact be at about 960ft (assuming all other errors were negligible).

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

3.7.5.2 Defining an MSAW / APM Boundary

If an ANSP is using both MSAW and APM, then the MSAW / APM boundary will have to be considered – this is the point on an aircraft's final approach where APM should take over from MSAW.

In many circumstances, the most appropriate point for APM taking over from MSAW is when the aircraft is established (or about to establish) on the localiser. However, in some environments, especially where there is significant terrain close to the final approach path, a softening zone (where APM and MSAW are both active) may be more appropriate. In short, ANSPs must consider the most appropriate logic for determining when MSAW and/or APM active depending on local conditions.

3.7.5.3 APM Approach Paths

The approach paths described in section 3.6 are intentionally quite simple. In some environments, more APM funnels will be required with slightly more complicated shapes.

Two particular local conditions have been identified.

Firstly, aircraft tend to join the ILS from below, and in level flight. In many airports, it may be appropriate to modify APM to allow aircraft to join the glide slope at say 3000ft without raising an APM alarm.

Secondly, if the APM is applied for parallel approaches or if there is an obstacle next to the approach path, it may be appropriate to narrow the horizontal limits of the APM approach funnel. The restriction may have to be applied one or other side of the runway centre line.

More information on modified APM approach paths can be found in appendix D-1 : Enhancement of APM for Geneva.

3.8 Development of a Policy and a Safety Case

3.8.1 Development of a Policy

The EUROCONTROL Specification for Approach Path Monitor requires that:

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

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

APM IS A GROUND-BASED SAFETY NET; ITS SOLE PURPOSE IS TO ENHANCE SAFETY AND ITS PRESENCE IS IGNORED WHEN CALCULATING SECTOR CAPACITY.
APM IS DESIGNED, CONFIGURED AND USED TO MAKE A SIGNIFICANT POSITIVE CONTRIBUTION TO AVOIDANCE OF CONTROLLED FLINGHT INTO TERRAIN ACCIDENTS BY GENERATING, IN A TIMELY MANNER, AN ALERT OF AIRCRAFT PROXIMITY TO TERRAIN OR OBSTACLES DURING FINAL APPROACH.

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

3.8.2 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 APM is available in the following three documents:

Appendix B-1: Initial Safety Argument for APM System

Appendix B-2: Generic Safety Plan for APM Implementation

Appendix B-3: Outline Safety Case for APM 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 APM System - Ideally, produced during the definition phase of a project to introduce a change to the ATM system e.g. to introduce APM. 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 APM 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 APM 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 APM

4.1 Introduction

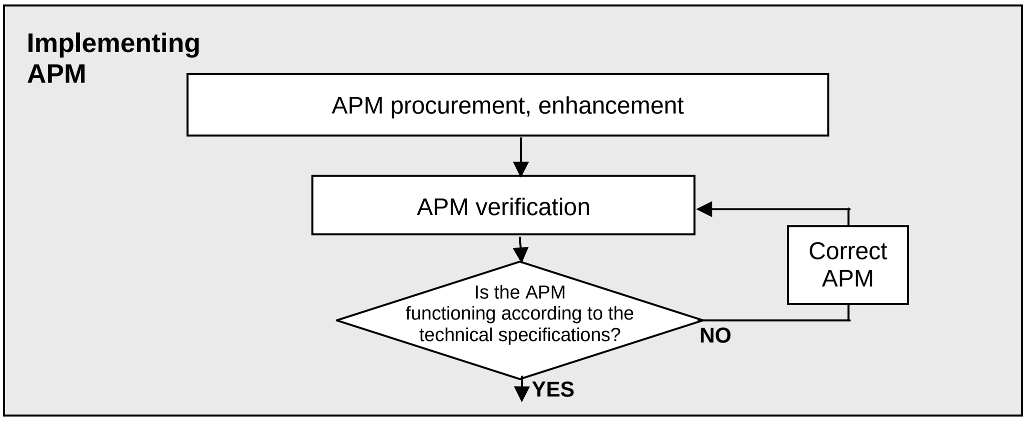

Figure 4-1: Phase 2 of the APM Lifecycle

ANSPs will normally choose between two alternative options when covering this lifecycle phase: (a) purchasing an APM 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 APM System describes a generic or reference APM 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 APM*. This gives guidance to the cost of implementing or enhancing APM to meet the requirements prescribed in the EUROCONTROL Specification for Approach Path Monitor

4.2 Procurement of APM

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

Manufacturers of APM 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.

APM, like other safety nets, may be included as part of a manufacturer’s ATM system. If this is the case, it is important to make sure that the APM is appropriate.

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

The purchaser should review the APM 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 APM 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 APM 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 APM?
What is the nature of the air traffic (VFR, IFR etc)?
What are the main features of APM, and are they in accordance with aircraft behaviour, tracker behaviour and local operational procedures? (Perhaps think about airports without ILS, track quality, unusual approach paths etc)
What SDP (tracking) data will be provided to APM, and is it of sufficient coverage and quality?
What other data will be supplied to APM? Flight plan data? Data input by the controller?
How will APM 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 APM approach paths defined in the operational system?
Is the maximum number of APM approach path definitions sufficient for current and future needs?
Can APM approach path definitions be dynamically activated / deactivated?
Are other APM capacities sufficient for both current and future needs?

Do the parameters (or range of values) allow APM to be optimised for the airspace?
What APM analysis tools are provided?
Is the APM capable of recording its internal values, and are they sufficient for testing?
Who will test APM? 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.

APM 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 APM.

4.3 Enhancement of an Existing APM

4.3.1 Introduction

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

The need to enhance APM 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:

- APM is giving irrelevant alerts (e.g. alerts for aircraft not under ATC)
- APM is producing too many false or nuisance alerts

- APM is not providing sufficient warning time, or provides sufficient warning time only in a limited number of situations

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

A practical example of APM system enhancement is given in *appendix D-1: Enhancement of APM for Geneva.*

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

When adding new logic to APM, 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 APM

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

It is not always necessary for APM to be technically enhanced. Many problems can be overcome or reduced by modifying the shapes of the APM approach path definitions. Furthermore, 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, such as airport helicopters, that are habitually within the envelope for APM but not necessarily on approach. These SSR codes should be inhibited from APM 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 APM. In particular, some deficiencies may be discovered by carefully inspecting the code or the system 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 APM processing).

- Check that APM is not using data that is too aged.

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

- Make sure that APM gives priority to the most critical alerts – i.e. deviations below the glide slope.

Certain problems, such as erroneous tracks (due to tracking blunders, radar reflections or erroneous transponders) are not usually solved by tuning the APM 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 introducing a conflict count would be inappropriate, because it would reduce the overall performance of APM. Instead, problems with the tracks introduced to APM should be solved within the wider surveillance system.

Furthermore, APM 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 APM may be made, for example, by the introduction of new algorithms or more flexible approach path definitions.

ANSPs should select enhancements that are in accordance with how aircraft behave in the airspace and local operational procedures. APM may also be improved through the use of aircraft derived data.

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

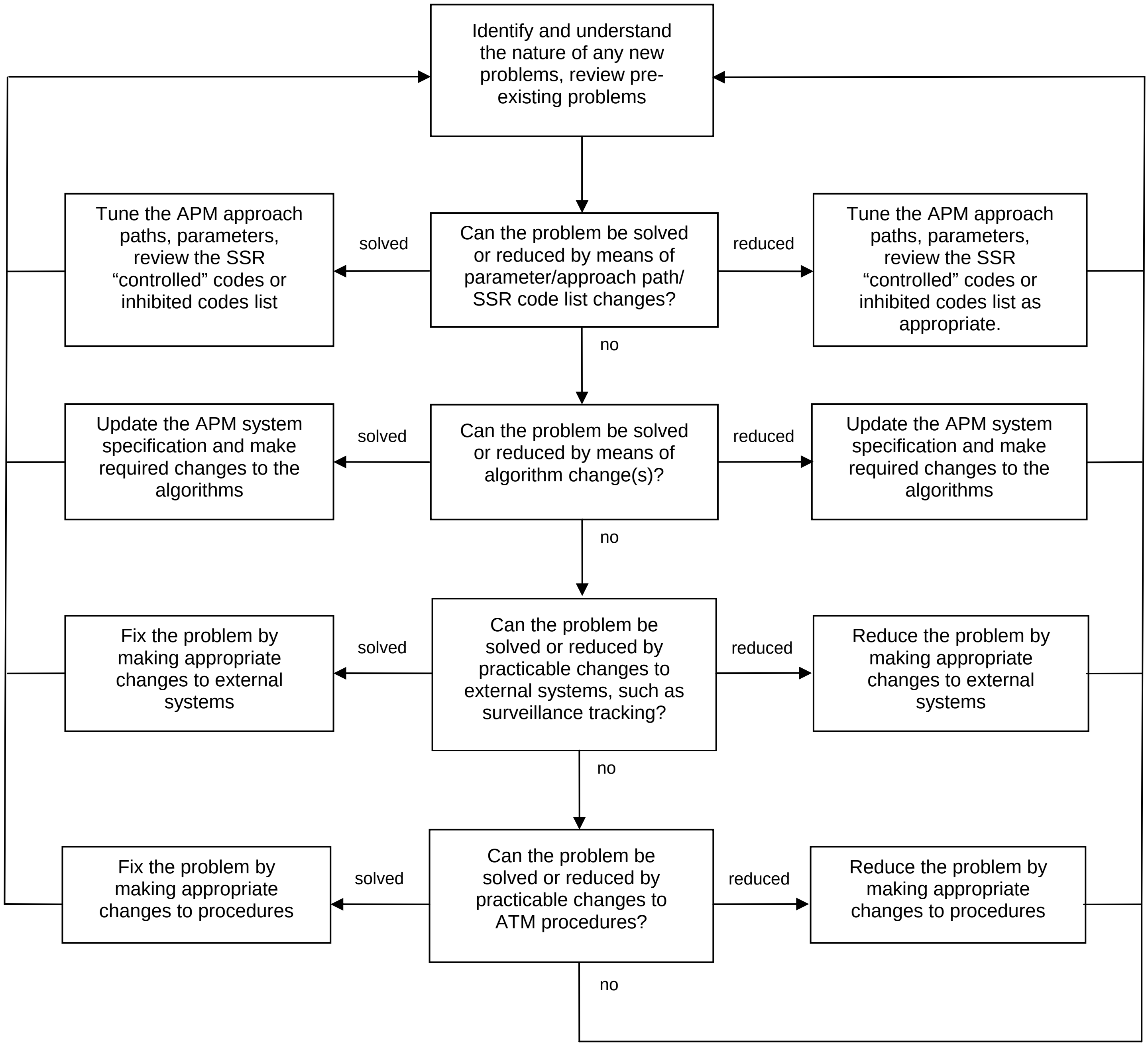

Figure 4-2 Idealised Troubleshooting Chart for APM

4.5 HMI Options for APM

4.5.1.1 Introduction

Controller's displays vary between the ECAC states, and likewise so does the presentation of APM alerts, and APM 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 APM is the only source of alerts, the HMI should be designed bearing in mind that other sources may be added in the future.

4.5.1.2 Requirement for Presentation of Alerts

The EUROCONTROL Specification for Approach Path Monitor requires that:

APM-09 APM alerts ***shall*** attract the controller's attention and identify the aircraft involved in the conflict; APM 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 as appropriate (e.g. in Control Towers). If a continuous audible element is included, an acknowledgement mechanism ***may*** be provided to silence an alert.

4.5.1.3 Visual Presentation

An alert is usually indicated visually either by the addition of a short coloured string ("APM" 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.

If APM is capable of generating different types of alert (e.g. above and below glide slope) then the type of alert should be easily identifiable by the controller.

4.5.1.4 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, potentially 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 APM alerts.

4.5.1.5 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 Approach Path Monitor:

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

4.5.1.6 Controller Inputs

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

4.5.1.7 APM Status Information

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

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

4.6 APM Verification

4.6.1 Verification Methods

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

It is normally the responsibility of the manufacturer to make sure that APM 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 their own checks.

4.6.2 Verification Using an APM Model

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

For an accurate APM 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 APM.

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

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

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

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

  (Note that for test scenarios, the APM approach path definitions, 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 APM logic are provoked. For some tests it may be convenient to use extreme or unlikely parameter values).

- Input the test scenarios into the operational APM system, recording the system tracks used by APM, the alerts and trace messages.

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

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

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

4.6.3 Verification without an APM Model

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

Without an APM model, one approach to verification is:

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

- Produce the operational APM – the operational APM 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 APM logic. The APM approach path definitions, 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 APM, 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 APM

5.1 Introduction

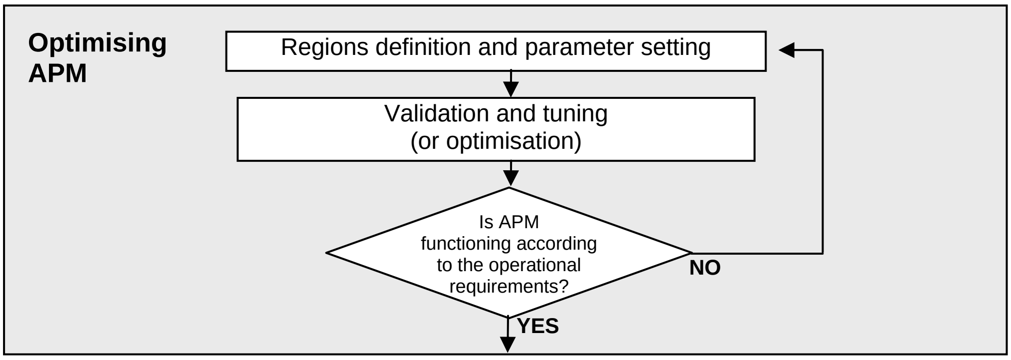

Figure 5-1: Phase 3 of the APM Lifecycle

The objective of APM system optimisation is tuning the APM approach path definitions and parameters to meet the requirements laid out in the EUROCONTROL Specification for Approach Path Monitor:

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

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

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

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

APM-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.– Warning time may be insufficient close to the runway threshold.

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

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

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

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

2. The capability to alter the APM definitions 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 APM 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 APM 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 APM parameter optimisation. Tools are indicated in bold type, files are shown in normal type.

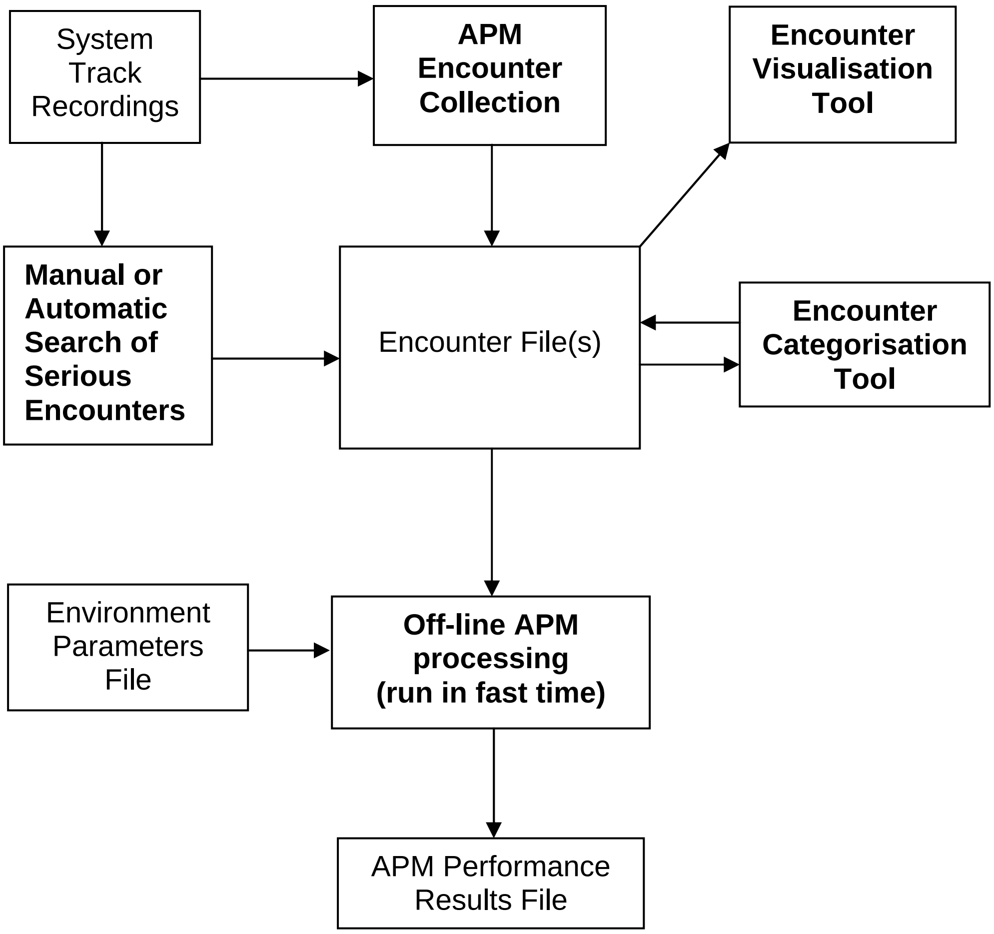

Figure 5-2 Tools and Files Required for Parameter Optimisation

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 APM 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 APM.

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 deviation from the nominal flight path or avoided a serious incident by a late manoeuvre.
Category 2	ALERT DESIRABLE – although there was no serious deviation from the nominal flight path, 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 deviation from the nominal flight path 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 APM.

Table 5-1 Definition of Encounter Categories

The encounter categorisation process needs to be done before inputting the encounter file into the APM 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 runway, nominal approach path and approach path definitions. 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 APM alert is desirable for particular borderline situations.

5.3.6 The Off-Line APM processing

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

The off-line APM 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 APM process will record various data, such as described in *appendix A*.

5.3.7 APM Performance Results

The APM 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 details of each alert must include:

- Identification of the aircraft encounter

- The time and duration of the alert
- The relevant APM approach path definition or runway

5.3.8 Requirements for APM 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 APM 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 APM Performance Requirements

In order to maximise performance, repeated runs with different APM 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 manoeuvres in all final approach segments 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 APM 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 APM 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 APM Systems

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

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

Whereas a model can run in fast time, a test APM system will be limited to (more or less) real time. To save manual effort, all the encounters may be best injected into APM 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 APM 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 APM. 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 APM approach path definition or runway 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 APM approach path definitions and general parameters. The user is also able to assess whether particular control positions would see more alerts than others.

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

5.4.5 Warning Time Measures for APM

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

6.1 Introduction

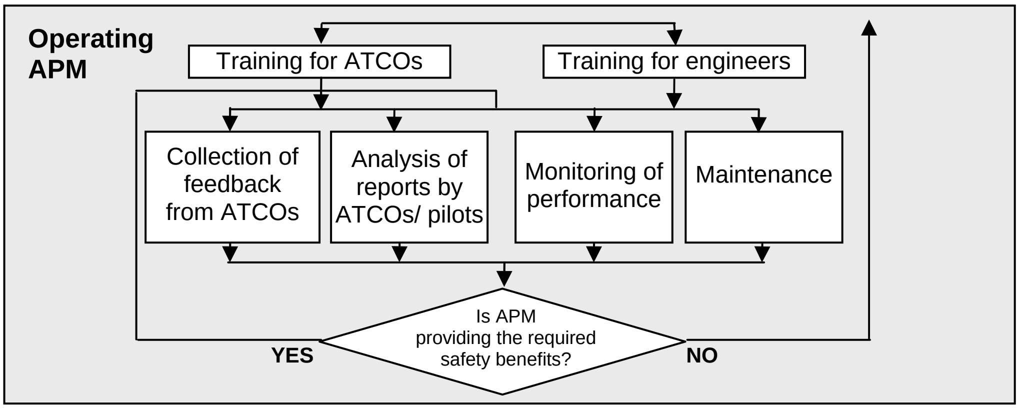

Figure 6-1: Phase 4 of the APM Lifecycle

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

6.2 Training for ATCOs

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

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

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

- The role of APM 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 (APM)
- How APM detects conflicts (indicating the main features of APM)
- Differentiation between desired and undesired alerts
- Which aircraft are eligible for APM

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

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

A number of tools, such as ATC test partitions, ATC simulators, APM 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 APM.

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

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

It is a useful exercise to collect and analyse all APM alert situations, not only to aid parameter tuning, but to provide informative examples than 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 APM parameters affect performance.

It is a useful exercise to compare the specific APM system with the reference APM 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 APM 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 APM algorithms.

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

6.5 Monitoring of APM Performance

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

6.6 Maintenance

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

Note: Appendices are contained in separate documents.

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