EUROCONTROL Guidelines for Approach Path Monitor - Part III

Implementation and Optimisation Examples

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EUROCONTROL Guidelines for Approach Path Monitor

Part III - Implementation and Optimisation Examples

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Abstract

These Guidelines specify the minimum requirements and provide comprehensive guidance for the definition, implementation, optimisation and operation of Approach Path Monitor (APM).

Part I describes the APM concept of operations as well as the specific requirements on APM.

Part II contains overall guidance for the complete lifecycle of APM.

Part III, **this document**, specifies a generic example of an APM implementation as well as detailed technical guidance for optimisation of APM.

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EXECUTIVE SUMMARY

These Guidelines specify the minimum requirements and provide comprehensive guidance for the definition, implementation, optimisation and operation of Approach Path Monitor (APM).

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

APM is a ground-based safety net that warns the controller about increased risk of controlled flight into terrain accidents by generating, in a timely manner, an alert of an unsafe aircraft flight path during final approach.

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

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

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

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

1. Introduction

1.1 Purpose of this document

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 an unsafe aircraft flight path during final approach.

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

The purpose of Part III of the EUROCONTROL Guidelines for APM is providing practical technical guidance material on APM, for use by engineers and other technical staff to help them meet the more technical requirements contained in Part I.

1.2 Structure of this document

Chapter 1 describes the purpose and structure of this document.

Chapter 2 describes a reference APM system in technical detail. This chapter allows the reader to understand how APM systems work and to compare various options for APM. The chapter specifies the inputs to the APM system, describes the method used to detect conflicts and the APM approach path definitions.

In chapter 3, guidance is provided to help in adapting the APM approach path definitions to the local air traffic environment.

The principles of system adaptation are described in chapter 4 and 5. The optimisation concepts are described in chapter 4 and the optimisation procedure is described in chapter 5.

Chapter 6 describes the data that should be recorded in order to do adequate testing of the APM system.

Chapter 7 comprises a description of test scenarios that could be used to test, validate, certify or inspect an APM system. Furthermore, these scenarios also serve to demonstrate the variety of types of situation for which APM may be expected to perform.

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 an unsafe aircraft flight path during final approach.

area proximity warning
A ground-based safety net intended to warn the controller about unauthorised penetration of an airspace volume by generating, in a timely manner, an alert of a potential or actual infringement of the required spacing to that airspace volume.

ATS surveillance service [Doc 4444]
Term used to indicate a service provided directly by means of an ATS surveillance system.

elevation [Doc 4444]
The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

false alert
Alert which does not correspond to a situation requiring particular attention or action (e.g. caused by split tracks and radar reflections).

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 hecto-pascals (hPa), and is separated from other such surfaces by specific pressure intervals.

Note 1: A pressure type altimeter calibrated in accordance with the Standard Atmosphere:

a. when set to a QNH altimeter setting, will indicate altitude;

b. when set QFE altimeter setting, will indicate height above the QFE reference datum;

c. when set to a pressure of 1 013.2 hPa, may be used to indicate flight levels.

Note 2: The terms "height" and "altitude", used in Note 1 above, indicate altimetric rather than geometric heights and altitude.

ground-based safety net [SRC28.06]	A ground-based safety net is functionality within the ATM system that is assigned by the ANSP with the sole purpose of monitoring the environment of operations in order to provide timely alerts of an increased risk to flight safety which may include resolution advice.
height [Doc 4444]	The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.
human performance [Doc 4444]	Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.
level [Doc 4444]	A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level.
nuisance alert	Alert which is correctly generated according to the rule set but is considered operationally inappropriate.
minimum safe altitude warning [derived from Doc 4444]	A ground-based safety net intended to warn the controller about increased risk of controlled flight into terrain accidents by generating, in a timely manner, an alert of aircraft proximity to terrain or obstacles.
short term conflict alert [derived from Doc 4444]	A ground-based safety net intended to assist the controller in preventing collision between aircraft by generating, in a timely manner, an alert of a potential or actual infringement of separation minima.
warning time	The amount of time between the first indication of an alert to the controller and the predicted hazardous situation. Note 1: The achieved warning time depends on the geometry of the situation. Note 2: 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

ADS	Automatic Dependent Surveillance
AGDL	Air-Ground Data Link
ANSP	Air Navigation Service Provider
APM	Approach Path Monitor
APW	Area Proximity Warning
ASM	Airspace Management
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATM	Air Traffic Management
ATS	Air Traffic Service
CFIT	Controlled Flight Into Terrain
CFL	Cleared Flight Level
DTED	Digital Terrain Elevation Data
EATCHIP	European ATC Harmonisation and Integration Programme
EATMN	European Air Traffic Management Network
EC	European Commission
ESARR	EUROCONTROL Safety Regulatory Requirement
ESSIP	European Single Sky Implementation
FAT	Factory Acceptance Test
FDPS	Flight Data Processing System
FUA	Flexible Use of Airspace
GAT	General Air Traffic
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ISA	International Standard Atmosphere
MOCA	Minimum Obstacle Clearance Altitude
MSAW	Minimum Safe Altitude Warning Note: Not to be confused with MSA (Minimum Sector Altitude)
MRVA	Minimum Radar Vectoring Altitude
MSA	Minimum Sector Altitude
MSL	Mean Sea Level
OAT	Operational Air Traffic
PoR	Point of Risk
QFE	Atmospheric pressure at aerodrome elevation *(or at runway threshold)*
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RVSM	Reduced Vertical Separation Minima

SAT	Site Acceptance Test
SES	Single European Sky
SESAR	Single European Sky ATM Research
SFL	Selected Flight Level
SID	Standard Instrument Departure
SRC	Safety Regulation Commission
SSR	Secondary Surveillance Radar
STAR	Standard Arrival Route
STCA	Short Time Conflict Alert
TOV	Time Of Violation
VFR	Visual Flight Rules

2. The reference APM system

2.1 Inputs to APM

2.1.1 System tracks

For the reference APM system, it is assumed that, at a minimum, the system tracks from SDP contain some information to identify the track (e.g. a unique system track number) and an estimate of the current position of the aircraft (X, Y, Z) measured in the system plane.

The current position of the aircraft is the fundamental data used to detect conflicts. Note that for APM the height value used is QNH corrected (i.e. derived from the pressure altitude and QNH corrected).

Although not relevant to all APM systems, track heading is used in the reference APM system to determine whether the aircraft is on approach to a particular runway.

Other data, such as system track ages or accuracy estimates, may be present in the system and these data items may be used by APM to assess the quality of the tracks. Tracks of insufficient quality may be rejected by APM.

2.1.2 Environment data

Environment data comprises APM approach path definitions (see section 2.3 for details), essential parameters, QNH data, QNH regions and local air temperature.

The QNH is used in the conversion of the pressure altitude into a true altitude, for the purpose of detecting APM deviations from the nominal vertical approach path.

QNH regions are polygons defining the areas to which a particular QNH value applies. There may be several QNH regions covering the area of interest.

APM systems may also use the local outside air temperature to refine the calculation of the true altitude.

The ICAO standard atmosphere has a pressure of 1 013.25 hPa and a mean temperature of 15°C at sea level. In simplistic terms, every 1°C deviation from this temperature will result in a deviation from the true altitude by approximately 0.4%. That is, if the air temperature at sea level were 5°C, an aircraft indicating an altitude of 1 000 ft (after QNH correction), would in reality be at about 960 ft.

In practice, the correction to be applied for temperature only starts to be significant below 0°C, and becomes critical at several thousand feet and very cold temperatures. For example if the air temperature at sea level were -20°C, an aircraft indicating an altitude of 5 000 ft (after QNH correction) would in reality be at about 4 290 ft. The aircraft would in fact be 710 ft lower than indicated.

2.2 The APM cycle

The APM processing occurs periodically. This may be a regular cycle time (e.g. 4 seconds), or driven by system track updates. On each APM cycle, the available system tracks are introduced to the APM processing, and any alerts are output to the ATC display system.

2.3 System tracks eligible for APM

Most essentially, the APM system must recognize which tracks belong to aircraft under responsibility of the ATS unit, 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. In many APM systems, 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, some APM systems allow the controller to selectively inhibit alerts for VFR aircraft, or selectively inhibit alerts based on call sign or SSR code.

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

- Have a pressure altitude (from surveillance data processing, either smoothed or unsmoothed)
- Be under the responsibility of the ATS unit.
- Have sufficient track quality
- Have an SSR code that is not on an APM inhibition list
-

2.4 APM parameters

Most APM systems employ a limited number of parameters. This means almost all the tuning is done by careful design of the approach path definitions.

Furthermore, many APM systems detect only deviations below the glide slope, whereas some systems also detect horizontal deviations or deviations above the glide slope.

In the reference APM system, the various conflict detection mechanisms are activated by just three parameters as shown in Table 1.

Table 1: Typical APM parameters

Name	**Description**	**Units**
AcitvateBelowGlideSlope	Activate Below Glide Slope Alerts	Boolean
AcitvateAboveGlideSlop	Activate Above Glide Slope Alerts	Boolean
AcitvateHorizontalDeviation	Activate Horizontal Deviation Alerts	Boolean

2.5 Approach path definitions and conflict detection

The reference APM system allows an indefinite number of approach path 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 volume or funnel describing the limits of the nominal final approach path.

If destination and/or runway 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.

In reality, the exact shape of the approach path volume differs between the various APM systems. Some APM systems allow the definition of more adaptable shapes (both in the horizontal and vertical) than shown here; these may be more appropriate for particularly busy airports or for parallel runway operations. Nevertheless, the shape of the approach path definition for the reference APM, described below and illustrated in Figure 1 and Figure 2, is fairly typical.

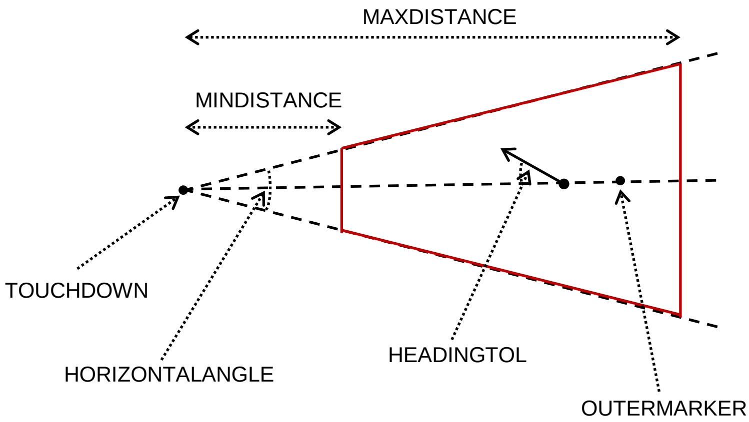

Figure 1: Typical approach path definition (horizontal view)

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.

HORIZONTALANGLE defines the angular extent of the horizontal area, and MINDISTANCE and MAXDISTANCE complete the horizontal 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 horizontal 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 horizontal APM alerts as described further. If the aircraft later deviates horizontally from the approach path then the aircraft is no longer considered on final approach for the purpose of vertical deviation calculation.

Note that the conditions for activating and deactivating the APM vertical and horizontal processing – i.e. the assessment of when an aircraft is on final approach – are normally a fundamental aspect of APM performance. It is essential that these qualifying conditions are appropriate for the local environment (including the surveillance environment, operational environment and available data).

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

If the aircraft is on the horizontal final approach path (aircraft heading within HEADINGTOL of runway approach) then the current vertical position is considered relative to the approach path shape, shown in Figure 2.

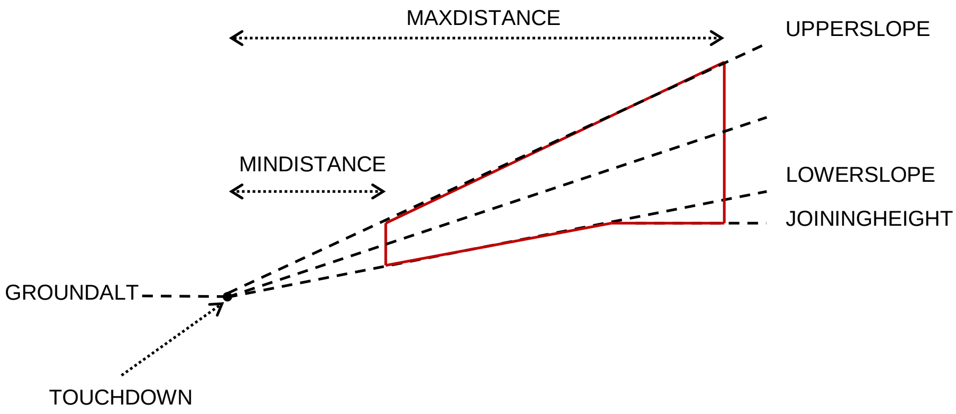

Figure 2: Typical approach path definition (vertical view)

The vertical section of the volume is defined by GROUNDALT, TOUCHDOWN, LOWERSLOPE, JOININGHEIGHT, UPPERSLOPE, MINDISTANCE and MAXDISTANCE as shown in Figure 2.

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

If **ActivateAboveGlideSlope** 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. Guidance to appropriate APM parameter values

3.1 Introduction

The purpose of this section is to provide guidance for tuning APM.

Since most APM systems use very few global parameters, the tuning of APM is generally a matter of carefully defining the approach path volumes for each runway.

3.2 Surveillance data quality and APM performance

The performance of APM is sensitive to the quality of the surveillance data and to some extent the tracker. Aircraft on final approach may be in the cover of just one or two radars, and this can lead to frequent coasting of the track (i.e. the track extrapolates in the absence of a surveillance plot). The result is that slight horizontal or vertical deviations may be exaggerated, producing nuisance APM alerts.

Too much or too little damping by the tracker, particularly in the vertical dimension could also lead to nuisance alerts.

If surveillance and track quality are proving to be an overriding issue for the APM system performance, the following courses of action could be considered:

- Improve the surveillance infrastructure close to the airports of interest
- In APM, avoid using tracks that are too old (i.e. they have coasted for too long)
- Seek to enhance or optimize the tracker (horizontal and/or vertical)
- If problems persist in the vertical tracking, consider using the last valid pressure altitude measurement instead (an automatic check for the credibility of each measurement should be made before use by APM)

3.3 QNH data quality

The performance of APM will also be sensitive to the quality of the QNH data. Erroneous QNH values may produce too many nuisance alerts, insufficient warning, or both. It may be appropriate to automatically disable APM when no up-to-date QNH data is available.

3.4 Prediction

Most APM systems use the current position of the aircraft; prediction is generally avoided because the errors in the track (particularly in the vertical) would lead to an excessive nuisance alert rate. Any prediction times in APM should be limited.

3.5 Horizontal and vertical deviations

In most APM systems, it should be possible to turn on or off the horizontal and vertical deviation detection separately, either by parameter switches or by adaptation of the individual approach path volumes.

The decision as to which types of alerts (horizontal, above glide slope, below glide slope) are appropriate is mainly an operational one, which may be influenced by system constraints and the number of nuisance alerts.

3.6 Size and shape of the approach volume

The size and shape of each approach volume must be tuned taking into account the nominal final approach path for the particular runway. Inflexible approach volume shapes may not be configurable for runways with unusual final approach segments.

Nevertheless, for the majority of runways, a simple approach volume definition like in the reference APM system should suffice.

An example is given below, using the reference APM approach path definition as an example. The runway has the characteristics shown in Table 2.

Table 2: Example approach path definition

Runway Threshold	Lat = N47°15’47’’ Lon = E003°05’40’’
Outer Marker	Lat = N47°06’57’’ Lon = E002°52’28’’
Glide Slope Elevation	3°
Final Approach Fix (distance from runway)	15 NM
Ground Altitude (at runway threshold)	450 ft

The TOUCHDOWN, OUTERMARKER and GROUNDALT parameters are already defined by the runway characteristics given in Table 2.

The glide slope angle is 3°, and it is judged that a LOWERSLOPE of 2° and an UPPERSLOPE of 4° would give acceptable detection of vertical deviations from the glide slope. Such selected values should always validated by monitoring the alerting performance of APM, or testing in an off-line system or model.

Extending the MAXDISTANCE out to the Final Approach Fix (FAF) would also be desirable, but a quick calculation shows that the lower bound of the volume defined by LOWERSLOPE would reach 3 180 ft at 15 NM from the runway threshold. Since a large number of aircraft at this particular airport intercept the glide slope in level flight at 3 000 ft, setting MAXDISTANCE to 15 NM and LOWERSLOPE to 2° would result in a large number of nuisance alerts. Therefore, it is decided to limit MAXDITANCE to 13 NM. At this distance the lower bound reaches 2 756 ft, giving some margin of error for aircraft joining the glide slope at 3 000 ft.

Many aircraft intercept the glide slope whilst they are in level flight. The JOININGHEIGHT parameter allows the approach volume definition to take this into account as part of the expected approach procedure. In this example, setting the JOININGHEIGHT to 2 756 ft will allow extension of MAXDISTANCE beyond 13 NM without causing a large number of nuisance alerts.

HORIZONTALANGLE and HEADINGTOL are set to 40° and 35° respectively, providing scope for aircraft not yet on the localizer to be included in the APM processing.

Finally MINDISTANCE is set to 2 NM. Below this distance, time is too short for any corrective action before the aircraft touches down. Furthermore, at this distance the upper bound of the approach volume is at 847 ft and the lower bound is at 424 ft. This height range is now approaching the precision and accuracy of the surveillance data. One erroneous pressure altitude measurement at this distance may be enough to provoke a nuisance alert. Therefore to avoid nuisance alerts, the choice is made that APM shall not operate within 2 NM to touchdown.

4. Optimisation concepts

4.1 Introduction

APM optimisation aims to maximise the number of conflicts which are alerted with adequate warning time and minimise the number of nuisance alerts. These objectives are, to some extent, incompatible with each other and therefore need to be prioritised. The priority is based on the perceived importance of the objective in contributing to the overall aim of improving safety. It is considered that minimising nuisance alerts is less important than alerting all conflicts with adequate warning time. However, a balance must be struck so that, for example, large warning times are not provided at the expense of an excessive nuisance alert rate.

In APM this balance between warning time and nuisance alert rate may be very challenging to achieve, particularly for aircraft close to the runway threshold.

Since APM performs no prediction, how warning time can be measured in practice needs addressing.

4.2 Analysis team composition

It is vital that the analysis and optimisation of ground-based safety nets performance is undertaken by a team which includes all the appropriate skills and experience. Function technical experts and data analysts must be accompanied by experienced ATC staff from the ATS unit for which the function is being optimised. Without the ATC input, the scenarios may not be categorised in a suitable manner.

Moreover, it is highly recommended to regularly exchange experience with adjacent ATS units that operate the same ground-based safety nets. Many mistakes have been made before and shared knowledge can help not to repeat these mistakes.

4.3 Scenario categorisation

4.3.1 Introduction

APM performance is measured by the numbers of genuine and nuisance alerts which are displayed to controllers, together with the amount of warning time provided for genuine alerts. Before these items can be measured, the APM analysts need to know which scenarios should have been alerted and which should not. In order to determine this, scenarios are divided into a number of categories.

Scenarios can be considered to range from “alert definitely required” to “alert definitely not required”, with a number of levels in between. The formal categories must be agreed between the analysis staff and ATC management before optimisation can proceed.

The scenario category is determined from recordings of the surveillance track data for the entire scenario. The category will depend on the actual and/or predicted deviations from the nominal approach path with respect to the appropriate criteria for the scenario. A series of suggested categories are described later in this section. They may be summarised as follows:

- Category 1 necessary alert
- Category 2 desirable alert
- Category 3 unnecessary alert

- Category 4 undesirable alert
- Category 5 void scenario

Using these categories, the theoretical aim of APM design and optimisation should be to alert all Category 1 and 2 scenarios and no Category 3, 4 or 5 scenarios. However, in practice the aim is to alert all Category 1 scenarios, virtually all Category 2 scenarios, very few Category 3 scenarios and virtually no Category 4 scenarios. Category 5 scenarios may or may not produce alerts and must normally be dealt with by improvements to the appropriate part of the ATM system. It may well prove impracticable to prevent APM occasionally alerting Category 5 scenarios, either by system adaptation or algorithm design.

4.3.2 Category 1

Category 1 scenarios are those where it is considered necessary that the controller's attention was drawn to the situation.

Category 1 scenarios include a number of Approach and Landing Accidents, including CFIT, and runway overrun, as well as serious deviations from the nominal approach path, plus those situations where such a serious incident was only avoided by means of a late manoeuvre.

Late manoeuvres are usually fairly easy to identify since they generally involve a sudden (and rapid) change in an aircraft's path to avoid, or minimise the consequences of, the potential hazard.

4.3.3 Category 2

Category 2 scenarios are those where it is considered desirable that the controller's attention was drawn to the situation.

Category 2 scenarios are those scenarios which, although involving some risk, can be dealt with by means of normal ATC instructions, such as "check your altitude", and are likely to be resolved without resort to emergency manoeuvres.

4.3.4 Category 3

Category 3 scenarios are those where it is considered unnecessary that the controller's attention was drawn to the situation. However, an alert was "predictable" or "understandable" in the circumstances and so would not cause a major distraction.

Category 3 scenario are situations which lead to a minor deviation from the approach path, but which are corrected by the pilot without ATC intervention. Some of these may be caused by turbulence.

4.3.5 Category 4

Category 4 scenarios are those where it is considered undesirable that the controller's attention was drawn to the situation.

Category 4 scenarios would typically be situations where the deviation from the approach path is with the normal bounds, considering nominal surveillance accuracy and typical aircraft avionics. An alert would have been distracting or unhelpful.

4.3.6 Category 5

Category 5 scenarios are those where errors elsewhere in the ATM system produced an apparent situation which did not in fact exist. These scenarios can therefore be considered as void but it may prove difficult to prevent them being alerted in some cases.

The nature of Category 5 scenarios will differ between systems. They cannot, therefore, definitively be described in this document. Some Category 5 scenarios will be immediately obvious as data errors whereas some may require thorough investigation to determine that the aircraft did not in fact fly the path as indicated by the tracker output.

4.4 Performance indicators overview

The precise nature of the performance indicators used to assess whether APM meets its design objectives may well vary between systems. However, the following indicators may be adopted as a general guide:

- Percentage of scenarios alerted for each scenario category
- Percentage of alerted scenarios which were considered to be nuisance alerts
- Percentage of scenarios worthy of an alert which did not give adequate warning time, although adequate warning time was available
- Mean achieved warning time for scenarios worthy of an alert where adequate warning time was available
- Mean achieved warning time for scenarios worthy of an alert where adequate warning time was not available
- Overall mean achieved warning time for scenarios worthy of an alert

Further information on performance indicators is contained in the following sections.

4.5 Warning time

4.5.1 Achieved warning time

APM will provide an amount of time in which the situation may be resolved “warning time”).

For most safety nets, the warning time is measured as the time between the safety nets alert and the conceptual Point of Risk (PoR).

However, for APM, the perceived point of risk may vary depending on the precise situation.

For lateral deviations or deviations above the glide slope, the achieved warning time would be measured as the time to the runway threshold – giving an indication of how long is available to resolve the situation.

However, for deviations below the glide slope the terrain could represent a much more imminent point of risk, and the achieved warning time would be better measured as the minimum of the time to runway threshold and the predicted time to terrain collision.

Flexibility should be allowed in the calculation of warning times, depending on the rationale behind the APM implementation.

4.5.2 Adequate warning time

An “adequate” warning time is one which allows sufficient time for controller reaction, communications, pilot reaction and aircraft response.

The amount of time needed for each of these four phases is dependent on a number of factors. External assessment, including the consideration of human factors issues, is necessary to determine the appropriate time for each phase.

Warning times are usually based on the time required for individual operations during normal circumstances. In some situations, such as when there are R/T difficulties, the “adequate” warning time may not be sufficient. However, it is impracticable to attempt to set warning times to cover all cases. In some situations, an aircraft may manoeuvre in such a way that it is not possible for APM to give an “adequate” warning time.

In theory, controller-alerting functions should alert before pilot-alerting functions. The adequate warning time should therefore be defined as being sufficiently large that the controller is alerted before the pilot.

For some APM implementations, it will be desirable to set different adequate warning times for above glide slope deviations, below glide slope deviations and lateral deviations.

4.6 Analysis tools

4.6.1 Introduction

APM implementations can require a considerable amount of optimisation and analysis. It is therefore important that such optimisation and analysis can be performed routinely and easily. This is most simply achieved via a series of automated software tools, as outlined below.

4.6.2 Off-line models

It is vital that APM performance can be optimised and monitored without affecting the operational ATC system. The most efficient way of doing this is probably via an off-line computer model which accurately replicates the algorithms of the (proposed) APM. It is preferable that the model is not contained within the main ATC simulation/test facility since it will be used intensively during optimisation phases and are therefore best used under the exclusive control of the APM analyst(s). The model should make detailed information available on the internal processes related to each scenario contained in each test so that it may be clearly understood why an alert was or was not given. The model should also produce the Performance Indicator information.

If the operational APM can be run in an off-line environment and generate adequate analysis information, it is not necessary to use an off-line model. However, using the operational APM for optimisation purposes must not have an impact on the functioning of the on-line ATM system.

A model should use exactly the same algorithms as the APM it is used to test, even if the actual programming source code is different. Different versions of an APM will, therefore require different versions of the model; otherwise the results of the optimisation may be invalid.

The model should be able to run in fast time (e.g. process one day's surveillance track data in a few minutes). To assist this, recording of surveillance track data can be reduced to just those tracks which are of concern. For optimisation purposes, each data set will need to be re-run many times against the model, with varying parameter sets..

4.6.3 Analysis display function

A means of displaying scenarios off-line is needed so that they can be examined manually, including an indication of when an alert would have been displayed. Scenarios may be displayed in 3D or otherwise in both plan and elevation view. A facility to print out the display for detailed analysis is often an advantage. In some circumstances, a pseudo radar display may prove to be useful, particularly so that controllers can assess the situation in a familiar context.

A means of displaying the locations of scenarios on a map of the relevant airspace may also prove useful, initially for checking that APM approach volumes have been located correctly and subsequently for identifying any part of the airspace with an unexpectedly high alert rate (alert hotspots). The facility to display actual tracks and/or modelled alerts on a map may prove useful when defining APM surfaces in the first place.

4.6.4 Categoriser

APM optimisations can potentially involve the examination of tens of thousands of scenarios, the vast majority of which should not result in an alert. It is therefore extremely useful to have an automated process to identify which scenarios require manual inspection and which may be discarded.

This tool, known as a “categoriser”, is totally independent from the simulation function of the APM model. The categoriser classifies scenarios into categories and will work retrospectively over the entire scenario.

The entire aircraft trajectories during the scenario are available for examination by the categoriser. The seriousness of the scenario is determined by considering the position of the aircraft in relation to the nominal approach path or an appropriate point of risk (e.g. the terrain)

Since the purpose of the categoriser is to reduce the number of scenarios which need to be inspected manually, the analysis staff should be able to have complete confidence that no serious scenarios will be discarded. The categoriser must therefore use different algorithms from those contained in APM and should be tuned to overestimate the seriousness of scenarios rather than underestimate. Any questionable scenarios should be classified as categories 1 or 2, rather than 3, 4 or 5. Only scenarios classified as categories 1 and 2 then need to be examined manually and possibly re-classified.

Determining whether scenarios are the result of data processing errors may require additional tools and expertise. For example, it may be worth checking the performance of the tracking system. Testing APM can highlight problems in other parts of the data processing chain. As optimal APM performance may only be achievable when such problems have been resolved, scenarios containing erroneous track information (category 5) may need to be identified and removed from the optimisation data set. This will allow APM to be optimised correctly for real situations but any performance figures derived from such a reduced data set must indicate the removal of category 5 scenarios.

It may also be of benefit to produce an “ideal” track by retrospectively smoothing the data. The “ideal” track will indicate more accurately the actual path(s) of the aircraft concerned and can be used to distinguish scenarios which are genuinely severe from those which appear to be severe because of substantial errors in the recorded surveillance track.

4.6.5 Warning time calculator

Calculating the actual and available warning times for each scenario should be automated since it is a large and repetitive task with considerable scope for human error.

The warning time is generally calculated as the time between the alert and the PoR (either the runway threshold or terrain).

Since a predicted PoR may be of more use than the actual PoR if avoiding action was taken, the warning time should be calculated for all forms of PoR used in the optimisation.

4.6.6 Scenario editor / generator

Even when surveillance data is recorded for several days, it may be necessary to increase the number and diversity of the serious (Category 1 and 2) scenarios comprising the test sample.

This may be done by generating such situations artificially or by manipulating the track data of recorded tracks. This is often useful for checking the performance of algorithms for situations not yet encountered in real data. However, more appropriate indications of the function’s operation are given by collecting serious scenarios from the live ATM system.

It is possible to create totally artificial scenarios but this is likely to take a great deal of effort if the scenarios are to test APM in a realistic manner. However, it may be considered necessary to use simulated scenarios for formal test purposes.

5. Optimisation procedure

5.1 Overview

The following diagrams are intended to provide a guide to the various stages likely to be involved in the optimisation of APM. They will not, necessarily, match the exact pattern of stages involved in specific optimisations.

Figure 3 shows the main tasks involved in the first optimisation of APM. Some of the initial tasks may not need to be undertaken when the system is re-optimised at a later date.

Figure 4 and Figure 5 each provide a more detailed indication of the steps involved in a particular task shown in Figure 3.

Figure 4 shows the steps taken in the actual iterative process of determining the optimal parameters.

Figure 5 shows the steps involved in the operational trial of APM and its parameters.

These diagrams assume that the algorithms themselves are correct. If errors are detected in the algorithms, or other parts of the software, then the process may be aborted at any point.

The tasks are explained in more detail in the rest of this section.

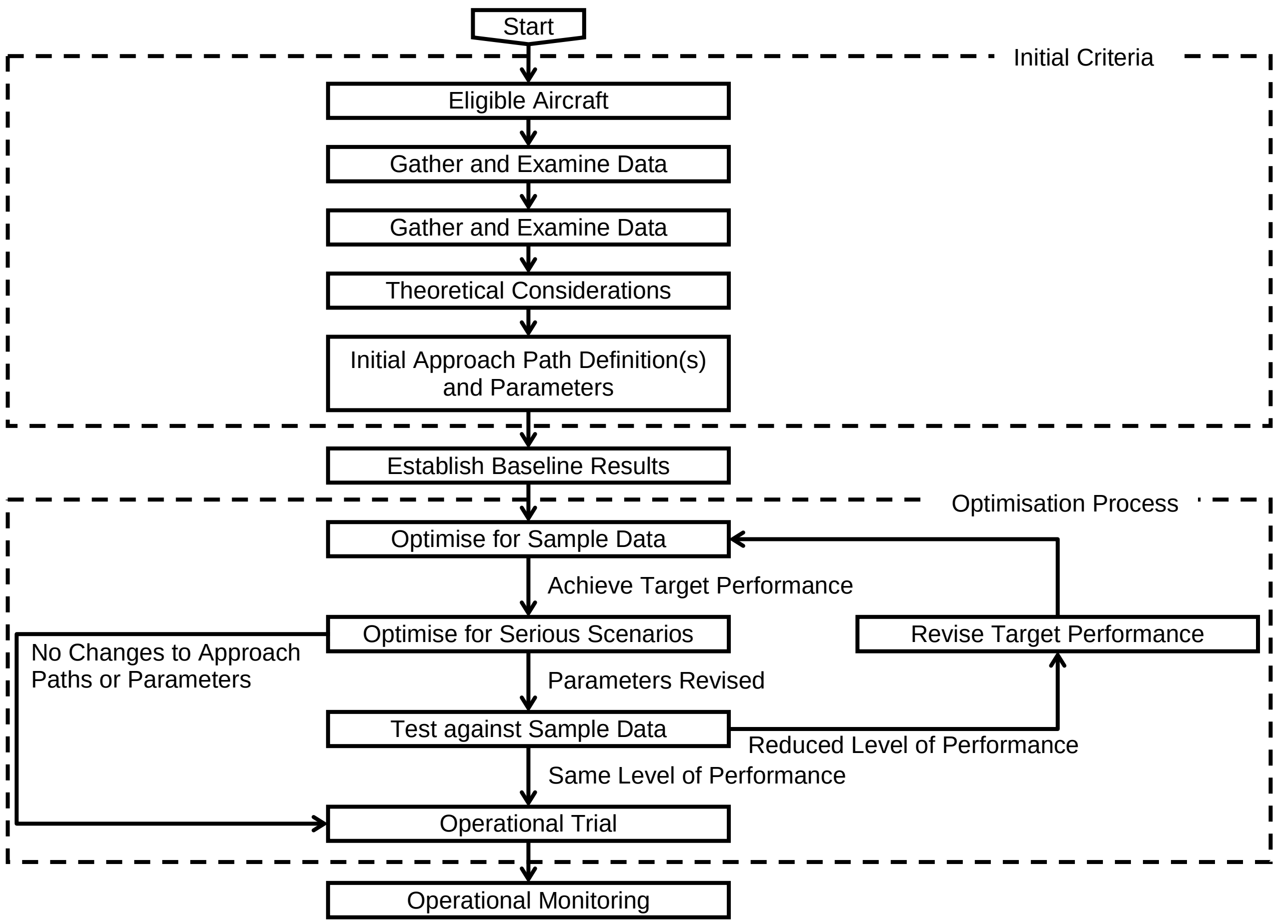

Figure 3: System adaptation tasks

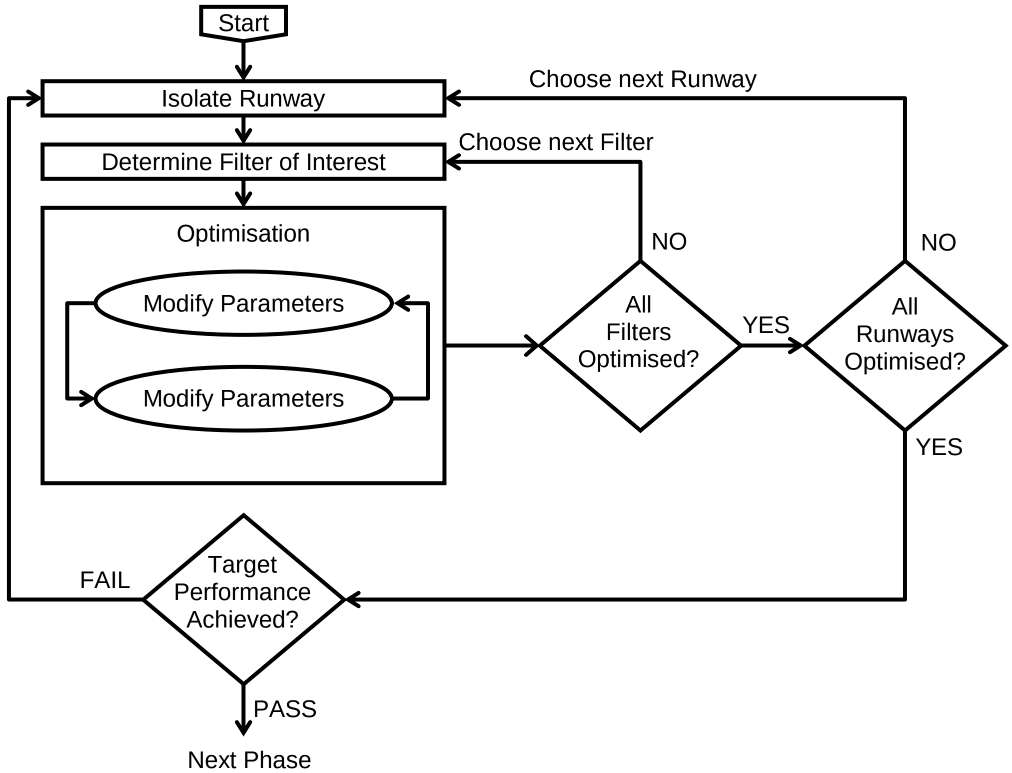

Figure 4: Iterative optimisation

Note: This iterative optimisation process applies to both sample and serious scenario data.

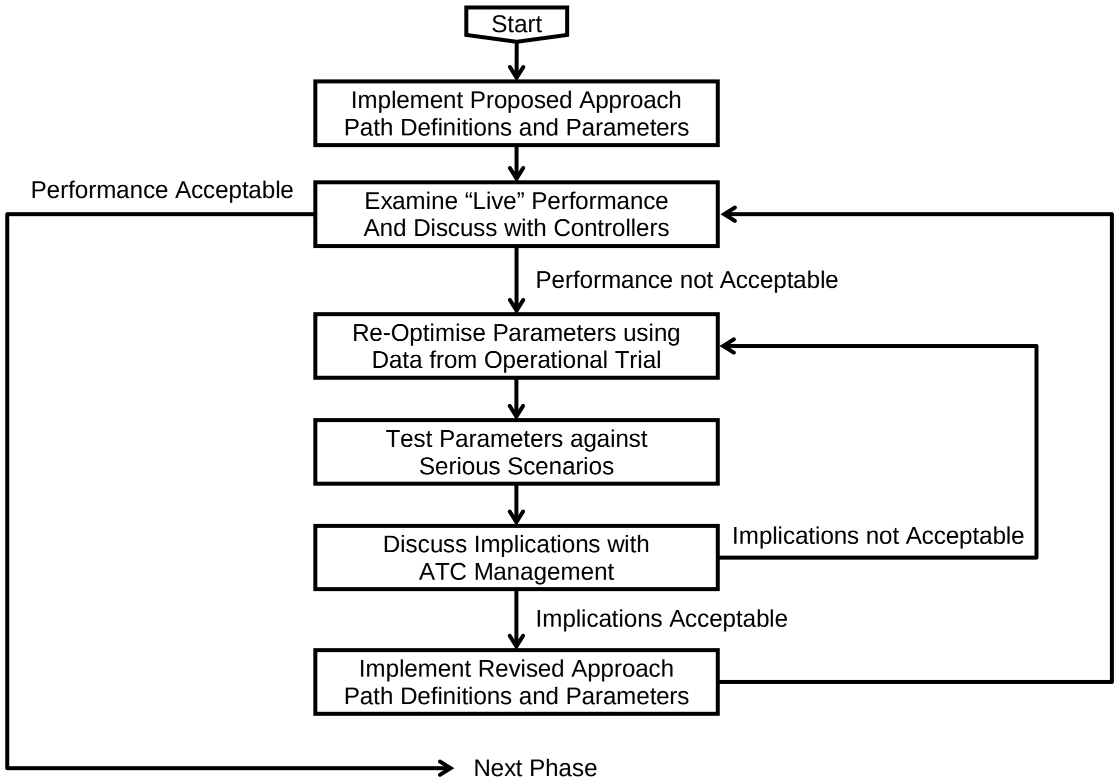

Figure 5: Operational trial

5.2 Initial criteria

5.2.1 Eligible aircraft

APM will normally use certain information about an aircraft in order to determine its eligibility for processing.

It is therefore vital that off-line APM simulations have correct information available as to the eligibility of the aircraft in the data sets.

Where a list of SSR codes is used to determine eligibility, this may well prove to be the part of APM which is most frequently changed. Test data sets which include “historic” data may need to be reviewed to take account of changes in SSR code allocation. It should not be necessary to re-optimise APM parameters to take account of SSR code changes.

APM systems that use a link to Flight Data Processing to indicate eligibility may not require SSR code lists. However, off-line simulations may need some other mechanism to indicate those aircraft which are eligible since there will not necessarily be a link to a Flight Data Processing simulator.

5.2.2 Data

5.2.2.1 Sample data

It is important that sufficient data is used in the optimisations. In general, one month’s data from a busy period should provide a sufficient base sample. However, certain geometries or airports may be under-represented and it may be necessary to modify existing data to create additional scenarios. The base sample should contain data for all typical traffic patterns.

It is possible to produce entirely artificial scenarios for test purposes. However, producing a sufficient number of realistic scenarios which conform to the appropriate traffic patterns may prove to be an excessively time-consuming task.

Ideally some data should also be collected at various times of the year and in different weather conditions since these are likely to affect the traffic patterns and aircraft behaviour on final approach.

5.2.2.2 “Serious” scenarios

The purpose of APM is to alert controllers to situations which have gone seriously wrong. Such situations are not an everyday occurrence but it is important that APM is adequately tested against precisely these scenarios. It is therefore important that the appropriate data is obtained for “serious” scenarios over as long a period as possible. These serious scenarios can then be used to check that a parameter set optimised for sample data still provides satisfactory performance for real problem situations.

Care should be taken to ensure that serious scenarios, collected over a long period of time, are still representative of what could happen in the current airspace environment. For example, if an approach procedure or airport equipage has been changed some previously recorded incidents may need to be discarded.

5.2.2.3 Scenario categorisation

All scenarios should be categorised before they are used in the optimisation process. To do this, all scenarios should be run through the automatic categoriser and those described as worthy of an alert should then also be analysed manually. Where the automatic and manual categories differ, the manual categories should be used when measuring the performance of the system.

Scenario categorisation should take place every time new data is acquired for test or optimisation purposes.

5.2.3 APM approach path definitions

Initial APM approach path definitions have to be determined before the optimisation process may start.

Determining the appropriate APM approach path definitions will normally involve discussions with controllers and examination of the traffic patterns on final approach evident from surveillance recordings and examination of aeronautical charts.

Within the area of responsibility there will be airports where it is not appropriate for APM to be active. The choice must be made whether to include an airport for APM coverage.

5.2.4 Theoretical considerations

5.2.4.1 Summary

Theoretical issues which need to be considered when determining APM approach path definitions and parameters include:

- Typical aircraft performance capabilities
- Typical local traffic manoeuvres
- Desired warning times
- Surveillance tracking performance
- ATC operational procedures

These issues will provide practical limits to the APM adaptation parameters.

5.2.4.2 Typical aircraft performance capabilities

Aircraft performance should be considered, particularly in relation to maximum descent rates, and vertical accelerations. Under normal ATC operations, typical rates of vertical acceleration are in the region of 250 ft/min/s. However, in an emergency, many aircraft would easily be able to exceed this.

5.2.4.3 Typical local traffic manoeuvres

In addition to the absolute limits on aircraft performance there will normally be additional limits imposed by different types of airspace and these also need to be considered. For example, aircraft routinely joining the glide slope for a particular runway level (at 3 000 ft say) may impose limits on the size and shape of the approach path volume.

5.2.4.4 Desired warning times

The minimum desired warning time is the time below which it may not be possible for a controller to issue an instruction and for the aircraft to have performed the necessary manoeuvre. This constrains approach path volumes. Local variations in aircraft types and operations may result in corresponding variations in the shape of the approach path volume.

5.2.4.5 Surveillance tracking performance

The behaviour of the vertical tracker should be considered when setting the APM parameters and designing the approach path volumes.

For example, it should be considered that tracker lag and (on occasion) vertical coasting can cause the aircraft to appear to deviate from the ideal approach path. Therefore, it is important that some vertical tolerance be added in order to avoid an excessive number of nuisance alerts.

Vertical rates, particularly at lower levels, can be inaccurate. This is especially true if the tracker is misled by one or more false pressure altitude measurements. Therefore, a conflict count mechanism may be used to reduce the number of nuisance alerts due to spurious tracks.

5.3 Baseline results

Once the initial approach path definitions and other parameters have been set up, the adaptation should be run against the sample test data. This produces a set of results to be used as the baseline for the system adaptation process.

When an optimisation is being performed on an APM system that is already in operation, the operational parameter set should normally be used to produce the baseline results.

5.4 Optimisation process

5.4.1 Procedure

The system adaptation process is undertaken at least twice - first with the sample data and then with the specially selected serious scenarios.

Precise instructions cannot be given for this process since its size and complexity will vary considerably between different systems, or even different optimisations of the same system. The efficient and effective optimisation of APM is dependent on the analysis team's skill and knowledge of the system under examination.

The way in which the results from individual filter/parameter set combinations are scored will be largely dependent on the specific implementation under examination. However, the basic purpose of a scoring system is to assess the relative performance of each parameter set against targets.

It will not normally be possible to examine all the possible combinations of parameter values, or even all the viable combinations. The expertise of the analysis team is crucial in determining which combinations should be examined and which may be ignored.

The iterative optimisation process should be performed for all runways and for all conflict detection filters (below glide slope, above glide slope, lateral deviation)

When all the iterations have been performed, the values for the Performance Indicators should be determined for the parameter set / data set combination.

5.4.2 Optimise for sample data

The system is initially optimised for the sample test data set. This should produce a parameter set which provides acceptable system performance in normal circumstances (according to the target performance requirements).

5.4.3 Optimise for serious scenarios

The optimised system should then be tested against a set of serious incidents, to ensure that all such scenarios lead to an alert and that, where possible, the warning times provided are adequate.

If the parameter set does not need to be re-optimised for the serious scenarios, it is suitable for use in an operational trial. However, if the parameter set does need to be re-optimised for the serious scenarios it must then be re-tested against the sample data.

5.4.4 Test against sample data

In theory, the parameter set that has been optimised for the serious scenarios should give the same or a lower level of performance when tested against the sample data than the parameter set which was optimised for the sample data. (If it gives improved performance, the original optimisation for the sample data was incorrect.)

If the revised parameter set gives the same level of performance, it can be adopted for use in the operational trial. If it gives a lower level of performance then further re-optimisation may be necessary. It may be that no one parameter set can give optimal results for both data sets. In this case some degree of compromise is necessary. The serious incidents should all be alerted but it may be that some degree of flexibility must be given to the warning times in some cases. Nuisance alert rates for the sample data may have to be allowed to increase above the minimum achievable values in order to alert all the serious scenarios.

5.4.5 Operational trial

When APM has been optimised and tested off-line it should be subjected to an operational trial in the "live" ATC environment before being declared fully operational. This is because of the risk that an off-line optimisation could miss "real world" problems.

An operational trial also gives controllers the opportunity to make comments which can be incorporated into the "final" system and should, therefore, help to develop confidence in the system. The operational trial presents a suitable opportunity for the system objectives to be explained to the controllers. If controllers are not aware of the objectives, and limitations, of the system then their participation in the trial will be of limited value.

An operational trial would normally perform the following functions:

- Ensure APM functions correctly in the operational environment
- Test APM under a variety of conditions, such as traffic levels and weather
- Provide information on APM to controllers
- Enable feedback from controllers on APM

An operational trial will also provide information on the controllers' perception of the nuisance alert rate. This is vital since an excessive number of nuisance alerts will lessen the impact of genuine alerts and thus reduce the potential effectiveness of APM. An acceptable nuisance alert rate can only truly be determined by operational experience.

The operational trial may highlight problems requiring further revision of the parameter set. This will involve the repetition of some tasks for the previous phases of the optimisation. If possible, the data from the operational trial period should be available so that proposed solutions can be tested on the scenarios which revealed the problems. Revised parameter sets should again be run against the serious scenarios data set.

5.5 Operational monitoring

Traffic patterns, airport equipage, SSR allocations and ATC practice all change with time. These factors have a bearing on the "optimum" parameter set for APM. System adaptation should, therefore, be regarded as a continuing process which does not necessarily cease once the system goes operational. The performance of the system should be kept under review and the optimal parameter set checked from time to time. It is also important to establish operational monitoring procedures so that technical problems may be detected as early as possible.

6. Guidelines for recording APM data

6.1 Introduction

When discussing data recording, it is essential to distinguish between data that is be recorded routinely, such as for system monitoring or legal replay, and data that is recorded only on occasion, such as for system verification.

The quantity of data that is required for full system verification is often very much bigger than is recorded during normal ATC operation. If a large quantity of data were recorded routinely the data recording media would fill very rapidly.

This section should be viewed as guidance only. The material is intended to give an indication as to the type and detail of data that is required for full system verification. Clearly, certain data items will not be relevant to all APM systems.

6.2 Routine data recording

In most ATC systems, data such as surveillance plots, system tracks, alert messages, flight plan data and controller inputs on the display are continuously recorded to allow a legal replay, if required at a later date.

The APM data that is recorded routinely generally includes the alert messages and may also include APM status (or alive, or heartbeat) messages. Other information related to APM may also be routinely recorded, such a flight plan data and QNH.

6.3 Occasional data recording

6.3.1 General

Data that is recorded for system verification should include not only the alert messages but also the data values and flags throughout the complete logical chain. In this case, the recorded APM data must contain sufficient information and must be precise enough to allow the correct functioning of APM to be verified.

If a test APM system is used for system adaptation then at the very least, the APM alerts must be recorded. However, it is often valuable to be able to analyse individual alerts in detail, in which case the full internal data values and flags can prove very informative.

In this section, an item of recorded data is defined either as required or as desirable. Required items are essential to allow a basic analysis of APM functioning, whilst desirable items of data may provide analysts with further valuable details.

Recorded data may be grouped as follows:

- Environment data (desirable, but may be obtainable from elsewhere)
- All system tracks available to APM (desirable on occasion, but bulky)
- System tracks that are subject to APM processing (required)
- Values calculated for the track during APM processing (required)
- Flags and results of conflict detection processes (required)
- Alert messages (required)

- Additional information such as QNH (required) or temperature (if relevant)

To conserve space, the data is best recorded in a binary format. The data will almost inevitably be recorded in time order. However, the format must allow information to be extracted on the basis of aircraft track trajectories (e.g. using a system track reference number), so that the inputs to APM and the APM functioning and output can be analysed on a track by track basis.

It is also useful to be able to select which data items will be recorded. For example, recording all the system tracks will take up a large amount of file space and may not be required on a regular basis.

6.3.2 Environment data

It is convenient to include all relevant environment data at the start of the data recording. This data should include all APM parameters, approach path definitions, as well as any other items related to APM processing such as QNH regions.

Without this information in the file, it may be difficult to establish the environment data in use at the time of the recording.

6.4 System tracks

Despite its inevitable size, it is sometimes desirable to record all the system tracks that are presented to APM. This would allow the correct functioning of the eligibility criteria and any pre-filtering to be tested.

Note that this same system track data may also be common to other system functions (e.g. other safety nets).

6.5 System tracks that are relevant to APM

All the tracks that are relevant to APM are required in the recorded data file.

Since APM systems do not usually include a coarse filter, some criteria need to be set to exclude the majority of tracks that are far from the runway(s) of interest. It is suggested that tracks should be recorded if they are eligible for APM processing and they are below a maximum height and within a defined distance of an airport of interest.

The track data must include all the track information relevant to APM in sufficient precision to allow a full analysis of each situation.

The information required for each track is listed below:

- System track number
- SSR code
- System track time
- System track eligibility information
- 3D state vector (X, Y, Z, VX, VY, VZ) and true altitude
- Track age and quality information used by APM
- Data from the flight plan such as the arrival airport and runway, IFR/VFR status, call sign

6.6 Values calculated before or during the conflict detection filters

The values calculated before or during the conflict detection filters should be sufficient to allow the APM functioning to be adequately examined. The information should include:

- The track number for the track of concern
- The current aircraft altitude
- The distance and estimated time to the runway threshold

All the values must be recorded with sufficient precision to allow a proper analysis to be done. Precision of at least 0.01 NM, 1 ft, 1 kt, 0.1 ft/sec and 0.1 s is recommended.

6.7 Flags and fine filter results

Flags are the true or false results of essential tests in the APM system. They allow the user to follow the logic of the APM processing and to see the reason why there was or was not a conflict for a particular track.

Depending on the features of the APM system, the flags required in the data file may include:

Flags before the Conflict Detection Filters

- Track is eligible for APM processing (or reasons for non-eligibility)
- Track is in an APM approach volume, on final approach
- Runway identifier

Above Glide Slope Deviation Flags

- Above glide slope deviation filter called
- Vertical distance from the glide slope
- Above glide slope deviation alert result

Below Glide Slope Deviation Flags

- Below glide slope deviation filter called
- Vertical distance from the glide slope
- Below glide slope deviation alert result

Lateral Deviation Flags

- Lateral deviation filter called
- Lateral deviation from the nominal approach (localiser) path
- Lateral deviation alert result

6.8 Alert messages

An APM alert message must be included in the recorded data for each cycle that an alert is in progress. The information required is:

- The system track number
- Runway identifier

- The nature of the alert, e.g. above glide slope, below glide slope, lateral deviation.
- Any other information relevant to the alert

6.9 Additional information

This data will depend on the particular APM system, but may contain

- Changes to the QNH
- Changes in the local temperature
- Runway activations/deactivations

7. Test scenarios for APM

7.1 Purpose of these scenarios

The purpose of this section is twofold:

- To provide a description of simulated scenarios that could be used to test the alerting performance of an APM system
- To demonstrate the variety of types of situation for which APM is expected to perform

Each test scenario indicates a target result, assuming that the reference APM system is used with given parameter values. However, in a real system the result of each scenario will depend upon the chosen APM parameter values and the capabilities of the particular APM system. Therefore, only some of the scenarios presented here might be valid for the APM system under test. In practice, some may require minor modification, or extra scenarios may be required to test specific elements of the APM system.

The test scenarios are useful to demonstrate the variety of conflict situations that can occur. It is not desirable to improve the alerting performance for one type of situation at the expense of alerting in other situations. Therefore, as part of the system adaptation process, the full variety of situations must be considered.

7.2 The test scenario situation pictures

Each test scenario includes a situation picture. This picture comprises a horizontal situation picture, a vertical situation picture and a brief description of the encounter. The horizontal situation picture presents a plan view of the situation. The vertical situation picture presents a vertical profile of the situation, with the flight level plotted on the y-axis against time on the x-axis.

7.3 List of test scenarios

The test scenarios are:

- Aircraft deviates below the nominal approach path
- Aircraft deviates above the nominal approach path
- Aircraft deviates horizontally from the nominal approach path
- Aircraft turns to intercept localizer below the nominal approach path
- Aircraft turns to intercept localizer above the nominal approach path
- Aircraft is level at 3 000 ft when it intercepts the glide slope
- Aircraft is on departure

7.4 Aircraft deviates below the nominal approach path

7.4.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft descending below the defined approach path volume.

7.4.2 Aircraft geometry

The simulated aircraft is arranged to start within an approach volume, and then to descend significantly below the nominal approach path. The aircraft is fully eligible for APM processing. The scenario is depicted in Figure 6.

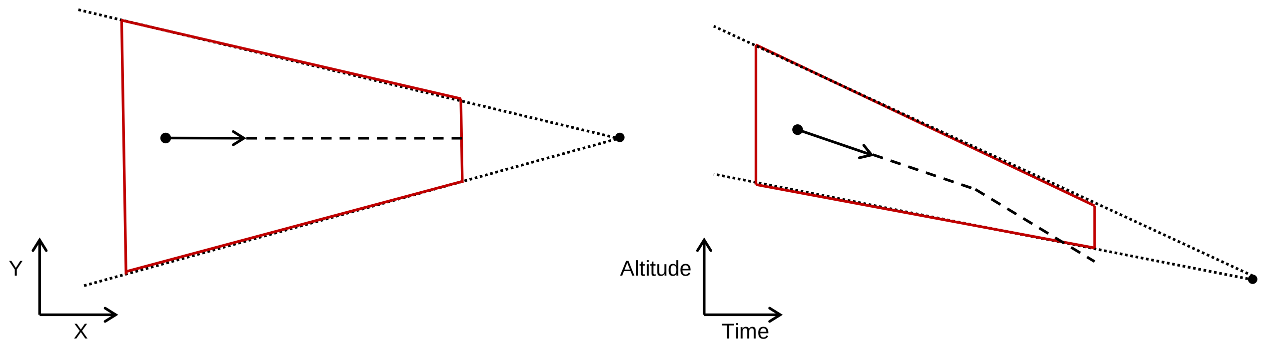

Figure 6: Aircraft deviates below the nominal approach path test scenario

7.4.3 Target result

The APM alert should be displayed as soon as the aircraft descends below the defined runway approach volume.

7.5 Aircraft deviates above the nominal approach path

7.5.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft climbing above the defined approach path volume.

7.5.2 Aircraft geometry

The simulated aircraft is arranged to start within an approach volume, and then to climb significantly above the nominal approach path. The aircraft is fully eligible for APM processing. The scenario is depicted in Figure 7.

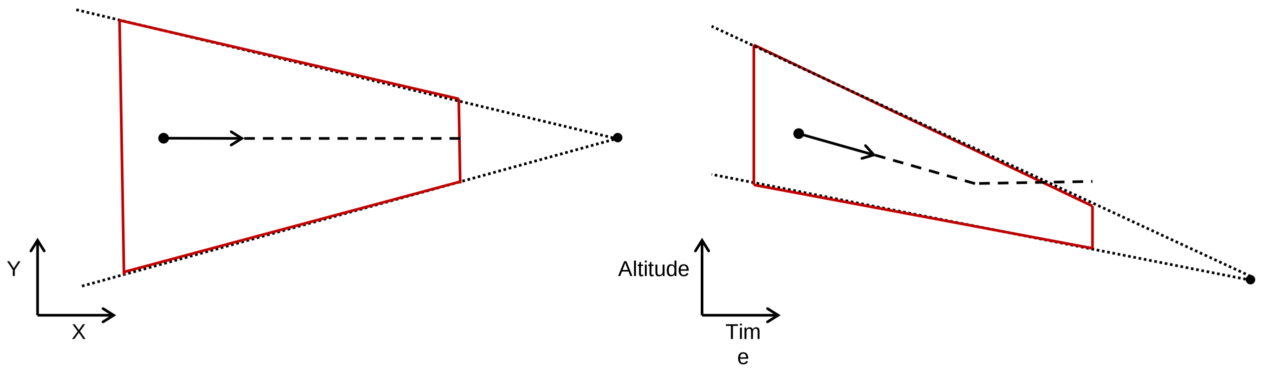

Figure 7: Aircraft deviates above the nominal approach path test scenario

7.5.3 Target result

The APM alert should be displayed as soon as the aircraft deviates above the defined runway approach volume.

7.6 Aircraft deviates horizontally from the nominal approach path

7.6.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft deviating horizontally from the defined approach path volume.

7.6.2 Aircraft geometry

The simulated aircraft is arranged to start within an approach volume, and then to horizontally deviate significantly from the nominal approach path. The aircraft is fully eligible for APM processing. The scenario is depicted in Figure 8.

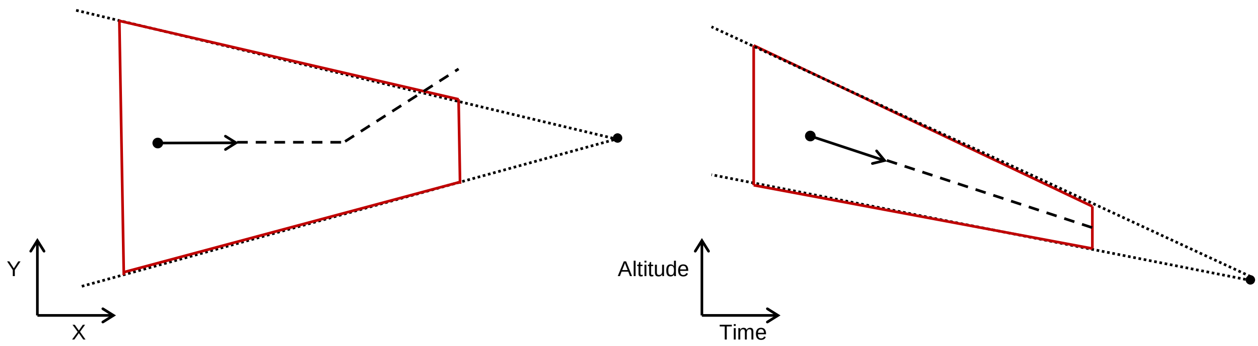

Figure 8: Aircraft deviates horizontally from the nominal approach path test scenario

7.6.3 Target result

The APM alert should be displayed as soon as the aircraft deviates from the defined runway approach volume.

7.7 Aircraft turns to intercept localizer below the nominal approach path

7.7.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft turning onto the localizer below the nominal approach path.

7.7.2 Aircraft geometry

The simulated aircraft is arranged to start outside an approach volume, and then to turn onto the localizer. The aircraft is below the nominal approach path. The aircraft is fully eligible for APM processing. The scenario is depicted in Figure 9.

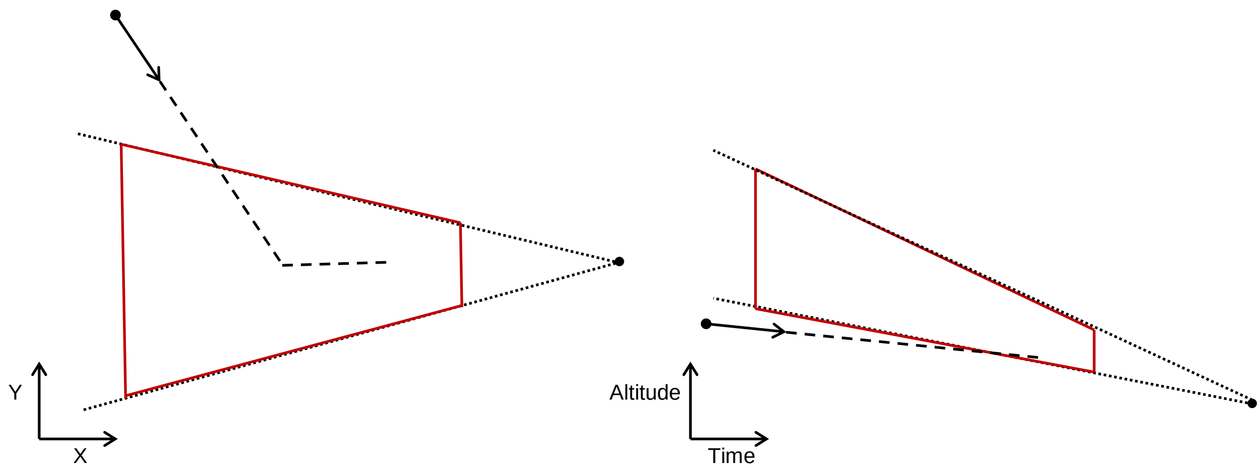

Figure 9: Aircraft turns to intercept localizer below the nominal approach path test scenario

7.7.3 Target result

The APM alert should be displayed as soon as the aircraft is in horizontal conformance with the runway approach volume (within the horizontal volume and heading sufficiently aligned with the runway).

7.8 Aircraft turns to intercept localizer above the nominal approach path

7.8.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft turning onto the localizer above the defined approach path.

7.8.2 Aircraft geometry

The simulated aircraft is arranged to start outside an approach volume, and then to turn onto the localizer. The aircraft is above the nominal approach path. The aircraft is fully eligible for APM processing. The scenario is depicted in Figure 10.

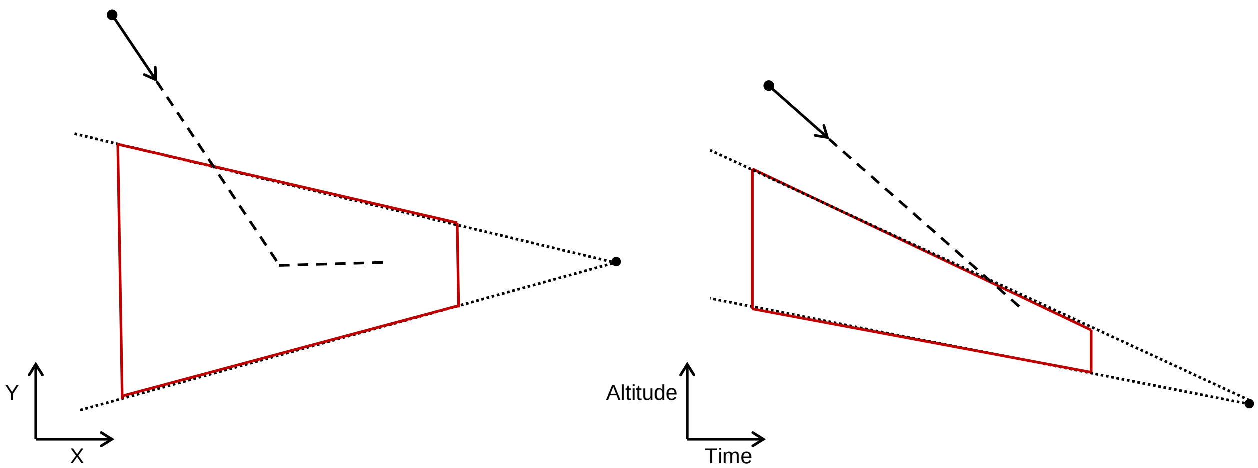

Figure 10: Aircraft turns to intercept localizer above the nominal approach path test scenario

7.8.3 Target result

The APM alert should be displayed as soon as the aircraft is in horizontal conformance with the runway approach volume (within the horizontal volume and heading sufficiently aligned with the runway).

7.9 Aircraft is level at 3 000 ft when it intercepts the glide slope

7.9.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft being level at 3 000 ft when it intercepts the glide slope.

7.9.2 Aircraft geometry

The simulated aircraft is arranged to start within an approach volume level at 3 000 ft, and to intercept and follow the glide slope. The scenario is depicted in Figure 11.

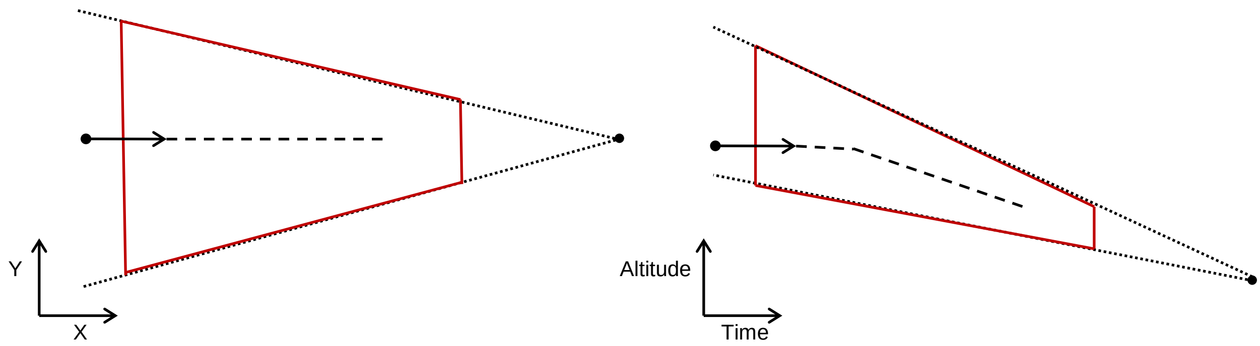

Figure 11: Aircraft is level at 3 000 ft when it intercepts the glide slope test scenario

7.9.3 Target result

Providing the APM volumes have been set up in concert with this type of approach, there should be no APM alert.

7.10 Aircraft is on departure

7.10.1 Objective

The objective of this scenario is to test APM performance in the case of an aircraft departing from a runway under APM protection.

7.10.2 Aircraft geometry

The simulated aircraft is arranged to depart the airport, fly into the runway approach path volume, proceed above the glide slope, and proceed out of the volume. The scenario is depicted in Figure 12.

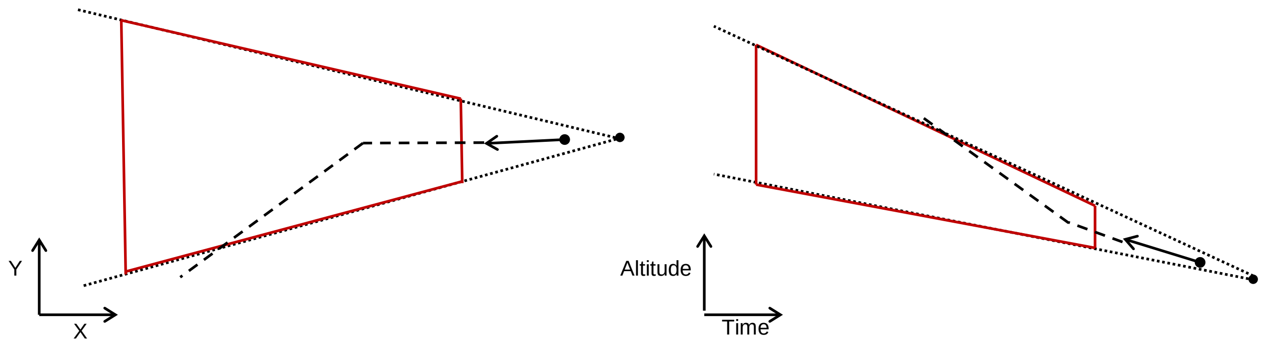

Figure 12: Aircraft is on departure test scenario

7.10.3 Significant parameters

There should be no APM alert for departures.

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