EUROCONTROL Guidelines for Short Term Conflict Alert - Part III

Implementation and Optimisation Examples

Edition: 1.0
Edition Date: 18/01/2017
Reference nr: EUROCONTROL-GUID-159

EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

EUROCONTROL Guidelines for Short Term Conflict Alert

Part III - Implementation and Optimisation Examples

DOCUMENT IDENTIFIER : EUROCONTROL-GUID-159

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

DOCUMENT CHARACTERISTICS

TITLE		
EUROCONTROL Guidelines for Short Term Conflict Alert Part III - Implementation and Optimisation Examples		
	Publications Reference:	GUID-159
	ISBN Number:	978-2-87497-083-2
Document Identifier	**Edition Number:**	1.0
EUROCONTROL-GUID-159	**Edition Date:**	18/01/2017

Abstract

These Guidelines specify the minimum requirements and provide comprehensive guidance for the definition, implementation, optimisation and operation of Short Term Conflict Alert (STCA).

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

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

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

Keywords

Safety Nets

STCA

Contact Person(s)	Tel	Unit
Stanislaw DROZDOWSKI	+32 2 72 93760	NMD/NOM/SAF

STATUS, AUDIENCE AND ACCESSIBILITY

Status		Intended for		Accessible via	
Working Draft	☐	General Public	☑	Intranet	☐
Draft	☐	EUROCONTROL	☐	Extranet	☐
Proposed Issue	☐	Restricted	☐	Internet (www.eurocontrol.int)	☑
Released Issue	☑				

DOCUMENT APPROVAL

See Part I – Concept and Requirements

DOCUMENT CHANGE RECORD

See Part I – Concept and Requirements

Publications
EUROCONTROL Headquarters
96 Rue de la Fusée
B-1130 BRUSSELS

Tel: +32 (0)2 729 4715
Fax: +32 (0)2 729 5149
E-mail: publications@eurocontrol.int

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

These Guidelines specify the minimum requirements and provide comprehensive guidance for the definition, implementation, optimisation and operation of Short Term Conflict Alert (STCA).

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.

STCA is a ground-based safety net that assists the controller in preventing collision between aircraft by generating, in a timely manner, an alert of a potential or actual infringement of separation minima.

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

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

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

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

1. Introduction

1.1 Purpose of this document

STCA is 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.

Part I of the EUROCONTROL Guidelines for STCA 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 STCA is providing practical technical guidance material on STCA, 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 STCA system in technical detail. This chapter allows the reader to understand how STCA systems work and to compare various options for STCA. The chapter specifies the inputs to the STCA system, describes the common algorithms used to detect conflicts and defines the STCA parameters. Some additional features are described which are present in only some existing STCA systems.

In chapter 3, guidance is provided in setting appropriate values for the parameters defined in the reference STCA system. Even without using a full parameter optimisation process, the effect of some of the parameters in STCA can be foreseen. The risks of using certain “poor” parameter values are highlighted, allowing the user to make a better choice of parameter values.

The principles of parameter optimisation 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 STCA system.

Chapter 7 comprises a description of test scenarios that could be used to test, validate, certify or inspect an STCA system. Furthermore, these scenarios also serve to demonstrate the variety of types of situation for which STCA is expected to perform. Some of the test scenario descriptions usefully show the effect of certain parameter values in the context of typical mid-air situations.

1.3 Reference documents

[Doc 4444]	ICAO Doc 4444: Procedures for Air Navigation Services - Air Traffic Management
[Doc 9426]	ICAO Doc 9426: Air Traffic Services Planning Manual
[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], Doc 9426] and [SRC28.06] as indicated.

alert	Indication of an actual or potential hazardous situation that requires particular attention or action.
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.
conflict [derived from Doc 9426]	Converging of aircraft in space and time which constitutes a predicted violation of a given set of separation minima.
false alert	Alert which does not correspond to a situation requiring particular attention or action (e.g. caused by split tracks and radar reflections).
ground-based safety net [SRC28.06]	A ground-based safety net is functionality within the ATM system that is assigned by the ANSP with the sole purpose of monitoring the environment of operations in order to provide timely alerts of an increased risk to flight safety which may include resolution advice.
human performance [Doc 4444]	Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.
nuisance alert	Alert which is correctly generated according to the rule set but is considered operationally inappropriate.
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.
separation [Doc 9426]	Spacing between aircraft, levels or tracks.
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
CFL	Cleared Flight Level
CPU	Central Processing Unit
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
FUA	Flexible Use of Airspace
GAT	General Air Traffic
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
LMD	Lateral Miss Distance
MSAW	Minimum Safe Altitude Warning
OAT	Operational Air Traffic
PoR	Point of Risk
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
SRC	Safety Regulation Commission
SSR	Secondary Surveillance Radar

STCA	Short Time Conflict Alert
TMA	Terminal Manoeuvring Area
TOV	Time of Violation
TSA	Temporary Segregated Area
VFR	Visual Flight Rules

2. The reference STCA system

2.1 Inputs to STCA

2.1.1 System tracks

For the reference STCA system, it is assumed that, at a minimum, the system tracks (of sufficient quality) contain some information to identify the track (e.g. a unique system track number) and an estimate of the current position and velocity of the aircraft. That is, the 3D state vector (X, Y, Z, VX, VY, VZ), measured in the system plane.

The 3D state vector is the fundamental information used to predict the aircraft’s future position. Note that for STCA prediction purposes the height value used is barometric (i.e. derived from the pressure altitude) and is usually smoothed using a tracker.

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

Although it is very rare for STCA to process aircraft without mode C, the feature is present in some systems. A variety of ways that STCA can process aircraft tracks without mode C is described in a later section.

Depending on the capabilities of the surveillance data processing, system tracks may contain an indication of the direction of turn of the aircraft, or even the turn rate. As part of option H (see later section), this information can be used in STCA to predict around the turn.

2.1.2 Environment data

Environment data comprises STCA regions, STCA parameters and QNH data.

The regions are defined as polygons with upper and lower height limits. They allow the selection of different sets of STCA parameters depending on the aircraft’s location in the airspace.

In many STCA systems, these regions are allowed to overlap. This makes setting up and optimization of STCA a simpler exercise, than in the case where the regions are not allowed to overlap.

STCA parameters control the criteria for detection of conflicts in each STCA region. In an STCA implementation, they should be optimized for each region of airspace to which they will be applied.

The QNH is used to convert the mode C height into a true altitude below the transition level, for the purposes of determining the applicable region for STCA. Note, however, that for conflict detection, the height is the barometric flight level derived from Mode C, and is not QNH corrected.

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.

2.1.3 Additional flight information

It is assumed that the reference STCA system is capable of using certain additional flight information.

Most essentially, the STCA system must recognize which tracks belong to aircraft under the responsibility of the ATS unit. Normally, if at least one of the tracks in a potentially conflicting pair is under ATC, then STCA processing will be performed.

Determination of whether an aircraft is under ATC or not, may be done in a variety of ways. In some STCA systems, the system track is correlated with a flight plan in a flight plan database. In other systems, the mode A code of the track is used to look up a list of “controlled” codes (i.e. those mode A codes normally assigned to aircraft under control of the ATS unit). One possible advantage of a mode A code look-up list is that it makes the STCA system more independent of the rest of the ATC system, and therefore able to fully function in some degraded modes However, the list of “controlled” codes would need to be kept up to date with the operational mode A code allocations.

Some STCA systems also allow the controller to exclude individual aircraft from STCA processing based on either the mode A code or the aircraft call sign.

Additional flight information presented to STCA may include the RVSM status of the aircraft. Indeed, with the introduction of RVSM operations in airspace above FL290, the RVSM status of the aircraft has become an essential input for most STCA systems.

As part of option E and F (see later sections), CFL and/or BFL, as input by the controller, and/or SFL as downlinked from the aircraft are presented to the STCA system. The STCA system uses the CFL and/or SFL or the BFL to improve its vertical prediction. As will be seen later, this can have a significant impact on the alert rate and the parameter values selected during parameter optimization.

2.2 Processing system tracks without Mode C

Some STCA systems have the option to process aircraft that have no mode C. If an aircraft has no mode C, and if no assumption is made about the aircraft’s height, it could conflict with another aircraft at any altitude, producing a very large number of unwanted alerts.

There are at least two recognized methods for processing aircraft that do not have mode C.

The first method is to allow the controller to manually input a flight level for aircraft without mode C. Tracks with a manually input flight level would be processed by STCA in the normal way, with the assumption made that the aircraft remains at its manually input flight level.

The other approach is that on loss of Mode C, an altitude band is assumed. This band increases with time. Once the Mode C loss reaches a particular age then no STCA processing is done on this aircraft, since the assumed levels are deemed unreliable.

2.3 STCA regions

Each region is defined as a horizontal shape with a floor and ceiling height. The horizontal shape may be composed by a polygon, a circle or a combination of polygons and circle segments. The floor and ceiling heights may be individually specified in terms of flight levels or altitude for each region.

In its definition, each STCA region is associated with a particular parameter group. This allows the selection of different sets of STCA parameters depending on the aircraft’s location in the airspace. Note that several regions may be associated with the same parameter group. For example several holding area regions could be assigned the same parameter group number.

The purpose of parameter groups is to allow STCA to be optimized for the type of aircraft behaviour in the various types of airspace, e.g.:

- En route airspace
- Terminal areas
- Approach sequencing

- Departure regions
- Holding areas

In addition, exclusion regions may be defined where no conflict tests are done, for example to cover airspace where VFR operations are common.

The 3D position of each track is used to determine which STCA region it belongs to. The precise details of the calculations for determining the STCA region are not significant for the reference STCA system. However, in many situations the two aircraft will be in different regions. Therefore some method will exist to determine the appropriate parameter group. In the reference STCA system it is assumed that some order of priority can be assigned to each parameter group, to allow one parameter group to be selected when the aircraft are in different STCA regions.

Some STCA systems allow for the selection of a completely different parameter group, for STCA region combinations (e.g. a parameter group for departure aircraft vs. holding areas).

Also, in some STCA systems, the system supervisor may activate and deactivate certain regions. For example, it may be useful to be able to activate and deactivate approach and departure regions when the operating direction of the runways is changed (e.g. from easterly approach to westerly approach), or to activate holding areas or Temporary Segregated Area (TSA) regions when they are in use.

If the aircraft flies below the transition level, it is appropriate to use the true (or QNH corrected) altitude when determining the STCA region.

2.4 STCA parameters

In the description of the reference STCA system, the parameters are defined in the each section, as they occur. They are shown in the text as bold type with no spaces, e.g. **LowerSeparationFlightLevel**.

Where a parameter is part of a parameter group (i.e. the value is selected according to the region of airspace), the specific parameter for group n, is shown in the text as **LinearPredictionLaterHorizontalSeparation[n]**.

As a convenient reference, all the parameters in the reference STCA system are listed in Table 1. Note that it is not necessary to memorize all the parameters here, since they will be described in detail in later sections:

Table 1: Typical STCA parameters

Name	Description	Units
LowerSeparationFlightLevel	ATC vertical separation rule boundary (lower)	ft
UpperSeparationFlightLevel	ATC vertical separation rule boundary (upper)	ft
CoarseFilterPredictionTime	Coarse filter prediction (or look ahead) time	s
CoarseFilterHorizontalSeparation	Coarse filter horizontal separation threshold	NM
CoarseFilterVerticalSeparation-[vsep]	Coarse filter vertical separation threshold	ft
HorizontalIFastDivergingVelocity[n]	Horizontal Fast Diverging Velocity Threshold	kt

Name	Description	Units
HorizontalFastDivergingSeparation[n]	Horizontal Fast Diverging Minimum Separation	NM
VerticalFastDivergingVelocity[n]	Vertical Fast Diverging Velocity Threshold	ft/min
VerticalFastDivergingSeparation-[n,vsep]	Vertical Fast Diverging Minimum Separation	ft
LinearPredictionTime[n]	Linear Prediction filter prediction time	s
LinearPredictionHorizontal-Separation[n]	Linear Prediction filter horizontal separation	NM
LinearPredictionHorizontal-SeparationDiverging[n]	Linear Prediction filter horizontal separation – diverging	NM
LinearPredictionVerticalSeparation-[n,vsep]	Linear Prediction filter vertical separation	ft
LinearPredictionHorizontal-Uncertianty[n]	Linear Prediction filter heading uncertainty	º
LinearPredictionVertical-Uncertainty[n]	Linear Prediction vertical rate uncertainty	%
UseCFLFlag[n]	Flag to indicate use of Cleared Flight Level	Boolean
UseSFLFlag[n]	Flag to indicate use of Selected Flight Level	Boolean
UseBFLFlag[n]	Flag to indicate use of Block Flight Levels	Boolean
CurrentProximityHorizontal-Separation[n]	Current Proximity filter horizontal separation	NM
CurrentProximityVertical-Separation[n,vsep]	Current Proximity filter vertical separation	ft
TurningPredictionTime[n]	Turning Proximity filter prediction time	s
TurningPredictionHorizontal-Separation[n]	Turning Proximity filter horizontal separation	NM
LinearPredictionImminentTime[n]	Linear Prediction filter imminent time	s
LinearPredictionConflictCount[n]	Linear Prediction filter conflict count	integer
LinearPredictionCycleCount[n]	Linear Prediction filter cycle count	integer
LinearPredictionWarningTime[n]	Linear Prediction filter warning time	s
SingleLevelOffReactionTime[n]	Reaction time for single vertical level off test	s
LevelOffVerticalSeparation[n,vsep]	Vertical level off test min. separation	ft
DoubleLevelOffReactionTime[n]	Reaction time for double vertical level off test	s
StandardTurnReactionTime[n]	Reaction time for standard turn test	s

Name	Description	Units
StandardTurnHorizontalSeparation[n]	Standard turn test, minimum separation	NM
CurrentProximityConflictCount[n]	Current Proximity filter conflict count	integer
CurrentProximityCycleCount[n]	Current Proximity filter cycle count	integer
CurrentProximitySafeHorizontal-Separation[n]	Current Proximity safe crossing horizontal separation	NM
TurningPredictionImminentTime[n]	Turning Prediction Filter imminent time	s
TurningPredictionConflictCount[n]	Turning Prediction Filter conflict count	integer
TurningPredictionCycleCount[n]	Turning Prediction Filter cycle count	integer
TurningPredictionWarningTime[n]	Turning Prediction Filter warning time	s

2.5 Summary of options for STCA

The various optional features in the reference STCA system are listed in Table 2.

Table 2: Optional features for STCA

Option	Description	Effects on STCA Performance
A	Split Track Alert Suppression	Suppresses alerts from split tracks and other such deficiencies in the surveillance data processing system
B	Military Formation Alert Suppression	Suppresses alerts from military formations
C	Fast Diverging Conditions to suppress Fine Filters	Switches off alert soon after aircraft are diverging
D	Use of uncertainty in conflict prediction	Takes account of uncertainty of future aircraft position. Can give extra warning time, as well as adding to the nuisance alert rate.
E	Cleared and/or Selected Flight Level used for Vertical Prediction in Linear Prediction Filter	Reduces nuisance alerts, particularly for level off situations. Can give extra warning time, but reduces warning time in the event of level bust.
F	Block Flight Levels used for Vertical Prediction in Linear Prediction Filter	Reduces nuisance alerts, particularly for level off situations. Can give extra warning time, but reduces warning time in the event of level bust.
G	Current Proximity Filter and Alert Confirmation	Can provide extra warning time for close proximity tracks
H	Turning Prediction Filter and Alert Confirmation	Can provide extra warning time for turning tracks – requires stable turn information.
I	Time for Standard Manoeuvre Test (vertical and horizontal)	Allows fine tuning of the timing of alerts and the nuisance alert rate

Option	Description	Effects on STCA Performance
J	Safe Crossing Test in Current Proximity Alert Confirmation	Suppresses some unwanted alerts in relatively safe crossing situations
K	Multiple Hypotheses	Can significantly improve alerting performance at the expense of increased optimization effort

All of these optional features are described in detail later, in the relevant parts of the reference STCA system description.

2.6 STCA under RVSM rules

The separation level is defined as the height boundary between the 1 000 ft and 2 000 ft applied vertical ATC separation, for non-RVSM approved aircraft. This boundary is defined by a parameter **LowerSeparationFlightLevel**. The value obviously depends on local operational ATC procedures, but typically is at or around FL290.

Further, with the introduction of RVSM rules, the allowable separation between aircraft in RVSM airspace will be either 1 000 ft or 2 000 ft, depending upon the RVSM status of the pair of aircraft involved. Again, the height band of the RVSM airspace is dependent upon local procedures, but is typically between FL290 and FL410. The upper boundary of the RVSM airspace is given by the parameter **UpperSeparationFlightLevel**.

Consequently, some of the vertical STCA parameters will be required to take appropriate values depending upon the vertical ATC separation rules that are applied. At its simplest, the requirement for these parameters will be to take two values, one for situations where the 1 000 ft separation standard is applied, and one for the 2 000 ft separation standard.

Parameters that are able to take two values, depending on the RVSM status and the appropriate vertical ATC separation standard, are indicated as follows:

ParameterName[vsep]
WHERE **ParameterName[1000]** is the value for the 1 000 ft separation standard and
ParameterName[2000] is the value for the 2 000 ft separation standard

For such parameters, the criteria for selecting the appropriate (1 000 ft or 2 000 ft) parameter values are defined below as follows:

The parameter value to be applied is given by **ParameterName[2000]** if:

- both aircraft are above **UpperSeparationFlightLevel**,
- or both aircraft are above **LowerSeparationFlightLevel** and in non-RVSM airspace,
- or both aircraft are above **LowerSeparationFlightLevel** and either of the aircraft is not RVSM capable

Otherwise the parameter value to be applied is given by **ParameterName[1000]**.

Note that if the RVSM capability of an aircraft is unknown (e.g. when no flight plan is available), some STCA systems assume that the aircraft is not RVSM capable, and apply 2 000 ft vertical separation. This may cause too many nuisance alerts close to airspace under the control of a different unit. In that case it is recommended to apply 1 000 ft separation for those aircraft.

Figure 1 clarifies the different possible situations in RVSM airspace.

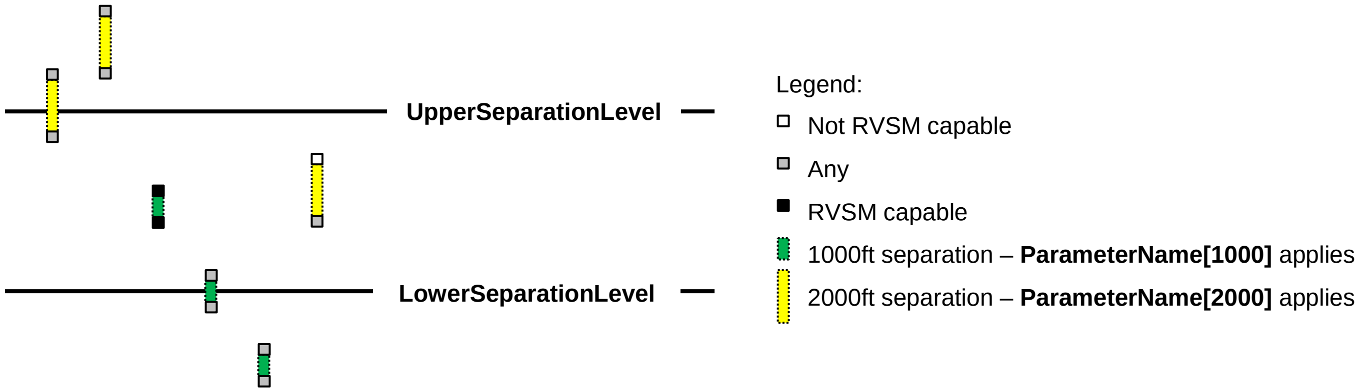


Figure 1: Applied vertical separation for aircraft in RVSM airspace

2.7 STCA processing stages

STCA processing consists of three main stages (as shown in Figure 2). These are:

- Coarse Filter
- Fine Filter(s)
- Alert Confirmation

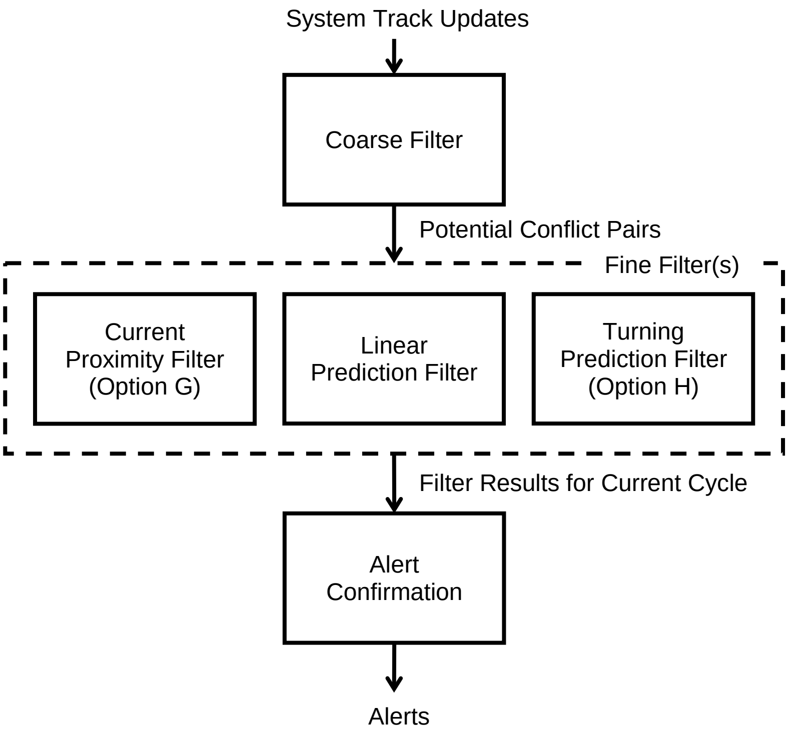


Figure 2: STCA processing stages

2.8 The STCA cycle

The STCA processing occurs periodically. This may be a regular cycle time (e.g. 4 s), or driven by system track updates. On each STCA cycle the available system tracks are introduced to the coarse filter, all the processing stages in STCA are executed, and any alerts are output to the ATC display system.

2.9 The coarse filter

The purpose of the coarse filter is to find pairs of system tracks that are of potential concern and that require further processing by the subsequent stages. Pairs of system tracks that could not come into conflict are eliminated at this stage, and hence much unnecessary processing is avoided (saving CPU load). An efficient coarse filter was particularly critical in the past, when computers were less powerful, and processing load had to be reduced to a minimum. Nowadays, an efficient coarse filter is still useful, especially if the fine filters are particularly processor intensive.

The determination of the region for each aircraft is a CPU intensive process. In order to save CPU in the reference STCA system, the coarse filter is executed as a region independent process before any region calculation is done. (Regions are then only determined for aircraft that have passed the coarse filter, using the defined polygons).

Note that some STCA systems run the region calculation first then have a region dependent coarse filter. This scheme is valid, and makes particular sense if the region computation is highly efficient and significantly different coarse filter parameters will be applied to different parts of the airspace.

The exact calculations done in the coarse filter differ from one STCA system to the next. However, the general principles are the same in most systems.

The coarse filter takes the current system track vectors and calculates whether the aircraft could potentially come into conflict within a certain prediction time. For a track pair to pass the coarse filter, a potential conflict must be detected in both the horizontal and the vertical dimensions, although the horizontal and vertical conflicts do not necessarily have to occur at the same time.

The reference STCA system contains a coarse filter, which uses the general principles outlined above. The prediction time in the coarse filter is defined by the parameter **CoarseFilterPredictionTime**.

If, within this time limit, both the following criteria are met then the track pair passes the coarse filter and is subject to further processing in the fine filters.

1. There is a predicted infringement of horizontal separation **CoarseFilterHorizontalSeparation**.
2. There is a predicted infringement of vertical separation **CoarseFilterVerticalSeparation[vsep]**.

CoarseFilterVerticalSeparation[vsep] is a parameter that is dependent upon the vertical ATC separation standard applied.

2.10 Handling deficiencies in the surveillance data processing system (option A)

Some surveillance data processing systems suffer from deficiencies such as split tracks (two system tracks generated from one aircraft), usually due to unresolved radar biases, split plots (generated by the radar plot extractor) or garbled mode A codes. In STCA systems where military aircraft are of concern, split tracks can be prevalent when aircraft are flying in formation. (A split track is caused because the tracker fails to associate all the surveillance plots to existing tracks – the left-over plots forming a new system track).

Under option A, the STCA system is able to suppress alerts from split tracks by recognizing certain features of the pair: Features that suggest a split track are:

- One track in a pair is created in very close proximity (of the order of 1 NM) to another track
- Both tracks have the same or a very similar mode A code (in the case of split tracks caused by military formations, the mode A code of the split track could resemble either the leader or the wingman)
- One of the tracks in the pair is not well established (a track creation flag, or track quality measures may indicate that it is not well established)

2.11 Handling military formations (option B)

Military aircraft may be subject to full STCA processing. In these cases, STCA can suffer from continuous nuisance alerts when military aircraft come into formation.

Under option B, the STCA system identifies and suppresses military formation pairs by virtue of their features:

- The wingman (usually not transponding) is not significantly ahead of the leader
- The mode A codes of the pair suggest a military formation
- The aircraft are in close proximity
- The aircraft have a similar heading
- The aircraft have a similar speed
- The aircraft have a similar height

2.12 Fast diverging conditions

Under option C, fast diverging conditions are tested, which have the useful effect of switching off the alert soon after the aircraft are diverging and the risk of conflict has disappeared. If the aircraft are diverging at a sufficiently high rate and are separated by a sufficient distance then it is assumed that there is no danger of conflict. Under this option, both the horizontal and vertical conditions are considered.

The horizontal fast diverging conditions are fulfilled if:

> Horizontal Diverging velocity >= **HorizontalFastDivergingVelocity[n]**
> AND
> Current horizontal separation >= **HorizontalFastDivergingSeparation[n]**
> WHERE the diverging velocity and current horizontal separation are calculated from the state vectors of the track pair

The vertical fast diverging conditions are fulfilled if:

Vertical Diverging Velocity >= **VerticalFastDivergingVelocity[n]**
AND
Current vertical separation >= **VerticalFastDivergingSeparation[n,vsep]**
WHERE the vertical diverging velocity and current vertical separation are calculated from the state vectors of the track pair

If the horizontal fast diverging conditions apply then the pair will not be processed by the linear prediction filter or the current proximity filter, and a "no conflict" result will be assumed from these filters for this cycle. However, the pair will still be processed by the turning prediction filter.

If the vertical fast diverging conditions apply then the pair will not be processed by any of the fine filters, and "no conflict" results will be assumed from all the filters for this cycle.

2.13 The linear prediction filter

2.13.1 Objective

The purpose of the linear prediction filter is to determine whether the track pair will simultaneously violate certain horizontal and vertical separation criteria within a given look ahead time. The prediction is made by a linear (straight-line) extrapolation of each aircraft's 3D state vector.

There a number of ways in which a linear prediction filter may be implemented, and furthermore, there are a number of optional features that may be included that significantly affect the performance of the filter.

The various implementation options are briefly described in the next subsection.

2.13.2 Optional methods for performing a linear prediction

2.13.2.1 Arithmetic and step-wise prediction

In STCA, there are generally two approaches to detecting whether an aircraft will be in conflict, both of which have potential advantages and disadvantages.

The first and most common approach is arithmetic; that is, solving the equations of the aircraft paths to compute the start and end time of violation. This is the method adopted by the reference STCA and described in detail in this document. Using the arithmetic approach, STCA determines the region (and the parameters to be applied) based upon the current positions of the aircraft.

The second approach is to make a step-wise prediction of each aircraft's future position. The position is extrapolated forwards in time with a step time of a few seconds. On each step the horizontal and vertical proximity of the aircraft pair is tested against the separation parameters. The advantage of the step-wise approach is that the STCA region can be re-evaluated on each step; this means that STCA is able to recognize the future crossing of ATC separation boundaries and apply conflict thresholds accordingly. The disadvantage of this approach is the CPU power required to make the prediction and, if done, re-computation of the STCA region on each step; this really puts the onus on an efficient coarse filter and region computation algorithm.

One appropriate solution is to adopt an arithmetic method in the vertical dimension and a step-wise method in the horizontal dimension.

If using the step-wise approach, the value of the step time must be considered carefully. The method requires the step-time to be short enough that a genuine conflict is not missed. When considering what step time to use, the relative speed of aircraft should be considered in relation to the separation parameters, if appropriate in both horizontal and vertical dimensions.

For example, consider that two aircraft could converge at 1 200 kt, in an airspace where the horizontal separation parameter is 5 NM. The step time required in order to guarantee detection of a conflict where both aircraft are converging on the same point in space is:

5 NM / (1/3 NM/s) = 15 s

However, this time is too large to guarantee detection of a conflict where the aircraft are not heading towards the same point in space, and therefore the step-time must be somewhat less than 15 s.

In the vertical dimension, the separation parameter may be perhaps 800 ft. Aircraft (particularly military) are capable of extremely high vertical rates. Hence, if a step wise calculation is done in the vertical dimension, the step-time must be considerably shorter than that in the horizontal dimension.

2.13.2.2 Adding in some uncertainty

There are various ways in which uncertainty may be included in the prediction.

In the arithmetic approach, this is most commonly done with tolerances added to the vertical rate, for example, the current aircraft vertical rate plus and minus ten percent. In the horizontal dimension, uncertainty may be included by adding heading or speed tolerances or by applying different parameter values at different points in the prediction. Note that applying different parameters values at different points using the arithmetic approach is not a trivial calculation.

In the step-wise approach, adding uncertainty is achieved simply by increasing the horizontal separation parameter value slightly on each step, to model the increasing uncertainty in the future aircraft position.

2.13.2.3 Use of CFL, SFL and BFL

Under option E, the CFL and/or SFL are available to the STCA system. CFL and/or SFL are used to modify the vertical prediction accordingly. The use of CFL and/or SFL is described in detail later.

Under option F, the BFL are also available to the STCA system. BFL are sometimes used in military airspace to define the upper and lower height limits within which an aircraft has been cleared to fly (often in order to perform military manoeuvres). Essentially, BFL work in the same way as two separate CFL for a track. If an aircraft is between the upper BFL and the lower BFL, the upper BFL is only relevant to STCA when the aircraft is climbing, and the lower BFL is only relevant to STCA when the aircraft is descending.

2.13.3 Overview of processing in the linear prediction filter

The horizontal and vertical separation criteria that are applied are given by:

LinearPredictionHorizontalSeparation[n]
AND
LinearPredictionVerticalSeparation[n,vsep]

The look-ahead time for the prediction is given by **LinearPredictionTime[n]**.

2.13.4 Horizontal prediction

Firstly, it is determined whether the aircraft will come within the horizontal separation criterion, **LinearPredictionHorizontalSeparation[n]** within the time limit **LinearPredictionTime[n]**.

If the aircraft are predicted not to infringe this threshold, then the filter rejects the pair, and no conflict is declared.

Otherwise, the time of horizontal violation start (THS) and the time of horizontal violation end (THE) are calculated based upon the same straight course assumption, where current time is defined as zero.

The horizontal situation is shown in Figure 3.

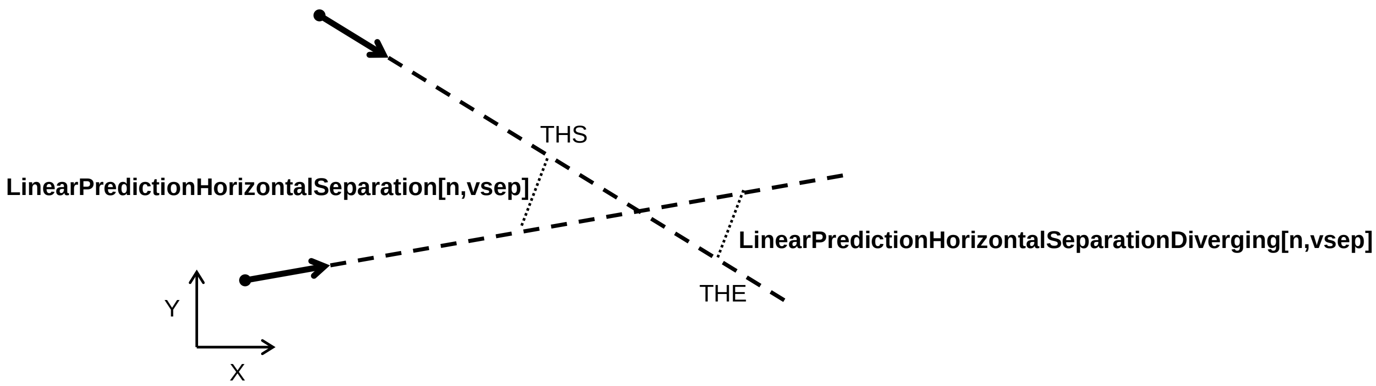


Figure 3: Horizontal prediction in the linear prediction filter

Different separation may be applied to tracks after they are predicted to be horizontally diverging, to reflect the reduced risk of conflict for these tracks. In this case, the parameter **LinearPredictionHorizontalSeparationDiverging[n]** is used to calculate THE after the point where the tracks are diverging.

If the tracks are horizontally diverging at the current time, then THS and THE are calculated using **LinearPredictionHorizontalSeparationDiverging[n].**

2.13.5 Vertical prediction

In the vertical dimension, calculations are made to determine whether the aircraft will come within the vertical separation criterion, **LinearPredictionVerticalSeparation[n,vsep]** within the time limit **LinearPredictionTime[n]**.

If the aircraft are currently diverging and outside the vertical separation criterion, or if the aircraft will not infringe the criterion within the prediction time then the filter rejects the track pair and no conflict is declared

Otherwise, the time of vertical violation start (TVS) and the time of vertical violation end (TVE) are calculated based upon the straight course assumption.

The vertical situation is shown in Figure 4.

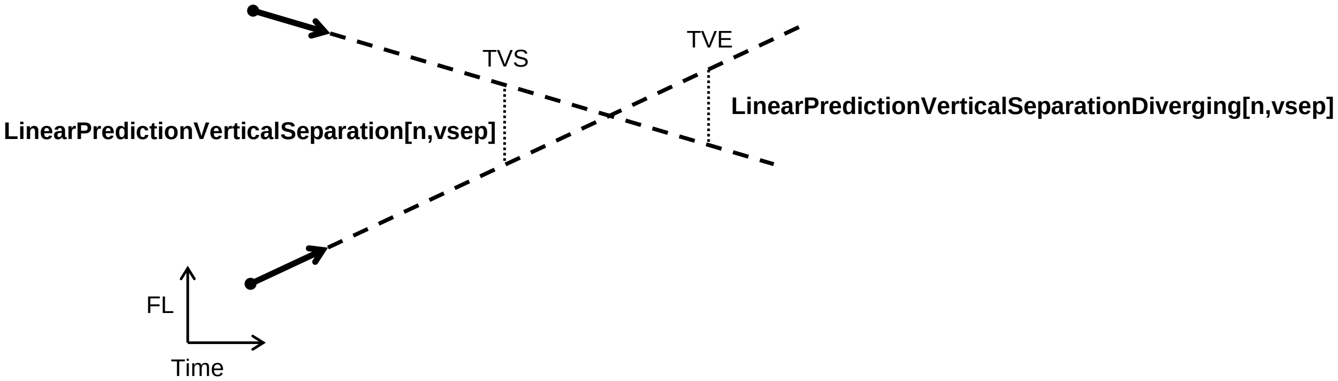


Figure 4: Vertical prediction in the linear prediction filter

2.13.6 Vertical prediction with use of the CFL and/or SFL

Under option E, the CFL and/or SFL are available to and used by the STCA system.

The use of CFL and/or SFL is region dependent and is selected for use in each region type by the parameters **UseCFLFlag[n]** and **UseSFLFlag[n]**.

Note 1: The use of CFL and SFL is identical as described below. Use of CFL is only appropriate if air traffic controllers are required to systematically input the CFL. Use of SFL requires appropriate surveillance infrastructure (Mode S or ADS-B).

Note 2: When both CFL and SFL are used, prioritization rules are needed for situations in which the CFL and SFL values disagree, taking into account that CFL and SFL values are unlikely to change simultaneously.

Note 3: Irrespective of the use of CFL and/or SFL in the STCA system it is good practice to draw the controller's attention, after an appropriate delay, to the fact that CFL and SFL values disagree.

When the CFL and/or SFL is used, it is taken account of in the calculation of the start and end times of vertical violation, TVS and TVE. Figure 5 shows what happens in a typical situation to the vertical violation times when a CFL and/or SFL is introduced.

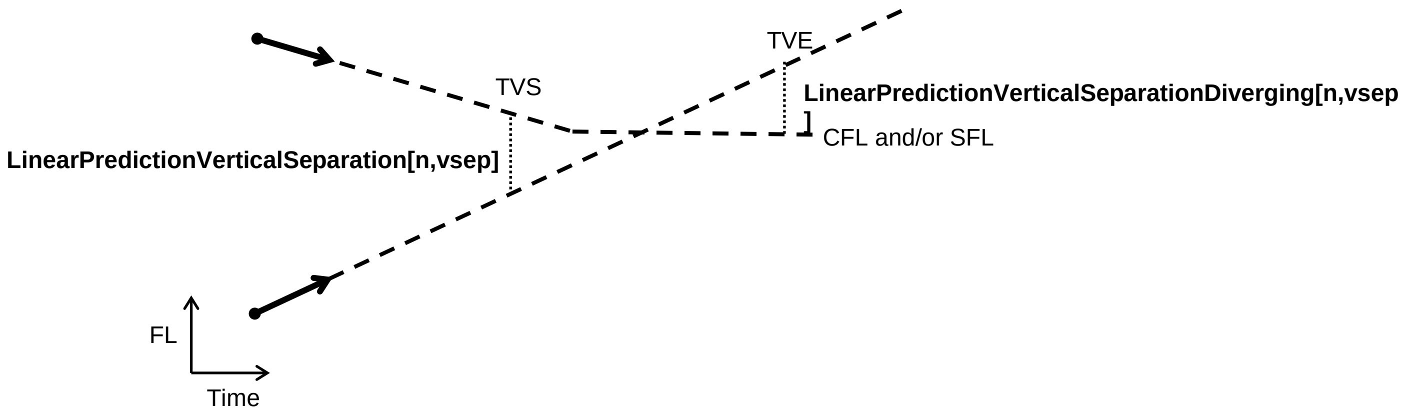


Figure 5: Vertical prediction using CFL and/or SFL

Note that, in this particular case, the effect of the CFL and/or SFL is to extend the time of the end of the vertical violation, TVE.

However, in other situations the time of start of vertical violation may be affected. For example, if the level off was predicted to be slightly earlier, then the CFL and/or SFL would also delay the onset of the vertical violation, TVS. Also note that, if both aircraft were cleared to the same flight level then the vertical violation end time would be limited only by the prediction time, **LinearPredictionTime[n]**.

In practice, the use of the CFL and/or SFL can result in an earlier alert being declared, if, as in this case, the CFL and/or SFL indicates a vertical risk extending into the longer term, and furthermore there is a horizontal violation predicted in the longer term.

However, in many cases, especially where both aircraft are predicted to be levelling off at separate ATC flight levels, the CFL and/or SFL (for one or both aircraft) can be very effective at suppressing nuisance alerts. See Figure 6.

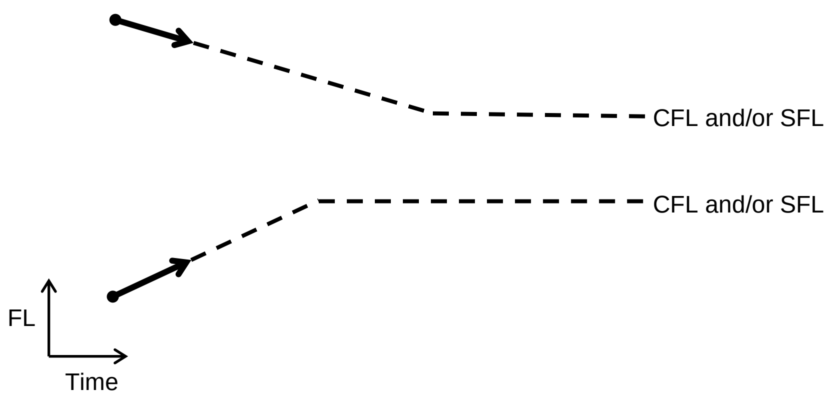


Figure 6: Vertical prediction using the CFL and/or SFL suppresses a nuisance alert

2.13.7 Horizontal and vertical violation overlap

Having calculated the horizontal and vertical violation intervals (THS, THE, TVS and TVE), further calculations are done to see if the two intervals overlap. If the two intervals overlap then the time of violation (TOV) is calculated. The time of violation is the time of the start of the overlap. See Figure 7.

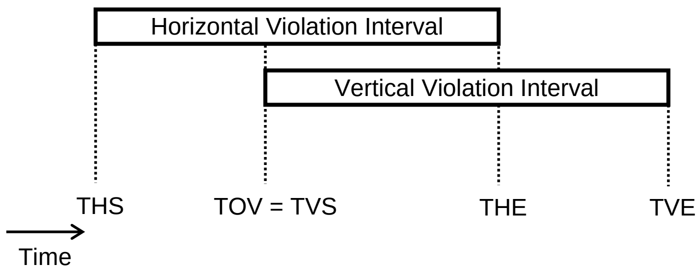


Figure 7: Calculation of violation overlap and TOV

In the example above, TOV is set to the start of the vertical violation interval, TVS. However, if the vertical violation occurred first TOV would be set to THS. Of course, it is also possible that there may be no overlap at all.

In the case of no violation interval overlap, the filter declares a “conflict miss” result. If there is an overlap, the TOV is calculated as indicated and the filter declares a “conflict hit”. However, the alert confirmation stage still has to run, so it does not necessarily follow that an alert message will be generated by STCA.

2.14 The current proximity filter (option G)

There are some situations where the linear prediction filter does not perform as well as desired. For example the linear prediction filter may be slow to provide an alert when aircraft are relatively close but closing very slowly. Therefore, the current proximity filter provides another means for detecting conflicts.

The filter detects STCA conflicts by comparing the current horizontal and vertical separation of the aircraft, H and dZ to the current proximity parameters, **CurrentProximityHorizontalSeparation[n]** and **CurrentProximityVerticalSeparation[n,vsep]**. That is,

IF H < **CurrentProximityHorizontalSeparation[n]**
AND

dZ < **CurrentProximityVerticalSeparation[n,vsep]**
THEN a conflict hit is declared from the filter
OTHERWISE a conflict miss is declared

Alternative versions of the current proximity filter can include a short predictive element in either the horizontal or the vertical dimension, or in both.

2.15 The turning prediction filter (option H)

There are other situations where the linear prediction filter might not provide an alert at the earliest opportunity. One example is where one aircraft is turning towards another.

To do the turning prediction, an indication of the turn direction must be supplied by the surveillance data processing. Ideally, the turn rate will be provided too. If no turn rate is provided, then a standard turn rate must be assumed by STCA. It is assumed that the turn rate is available in the reference STCA system.

If one aircraft is turning then the prediction proceeds around the turn, in a step-wise fashion, at the turn rate provided, for a time given by **TurningPredictionTime[n]**, whilst the other aircraft is predicted to continue over the duration on a straight course.

However, if both aircraft are turning, then the prediction around the turn is done for both aircraft.

At each step around the predicted trajectory of the aircraft, their horizontal separation is calculated and is compared to the horizontal separation parameter, **TurningPredictionHorizontalSeparation[n]**.

To declare a conflict result, the filter must detect simultaneous horizontal and vertical violations.

In the reference STCA system, the linear prediction filter is run before the turning prediction filter. This means that the vertical violation interval that has already been calculated and the variables TVS and TVE are passed to the turning prediction filter.

A conflict hit will be declared by the turning prediction filter if, on a step of the prediction:

- One aircraft (or both) is (are) turning towards the other
- The separation as a result of the turn (or turns) is less than **TurningPredictionHorizontalSeparation[n]**
- The horizontal violation occurs within the vertical violation interval

The step on which the conflict is first detected is sufficient to declare an alert from this filter. The time of violation for this filter (TPTOV) is set to the time of this step, and will be used later in the alert confirmation stage.

2.16 Alert confirmation

2.16.1 Objectives

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

- To test if a conflict is imminent and an alert is required immediately
- To suppress an alert that might be caused by spurious track data
- To suppress an alert that might be caused by a transitory situation
- To test whether an alert is required on this cycle, or should be delayed, with the hope that the situation will become resolved before an alert is necessary

- To continue an alert when there are temporary perturbations in the track data.

2.16.2 Options for alert confirmation

There is some variability in how alert confirmation is implemented in different STCA systems.

The design and tuning of the alert confirmation stage can have the greatest effect on STCA performance.

Although the exact design is not necessarily important, it is nevertheless, absolutely essential that the alert confirmation stage meets its overriding objective to provide an immediate alert when the situation indicates a serious or imminent conflict.

The alert confirmation stage presented here in this section is a good example because the imminent conditions are tested for first, and override less important tests.

If multiple filters are employed under option G or option H, then the confirmation of the alert is assessed independently for each filter as shown in Figure 8.

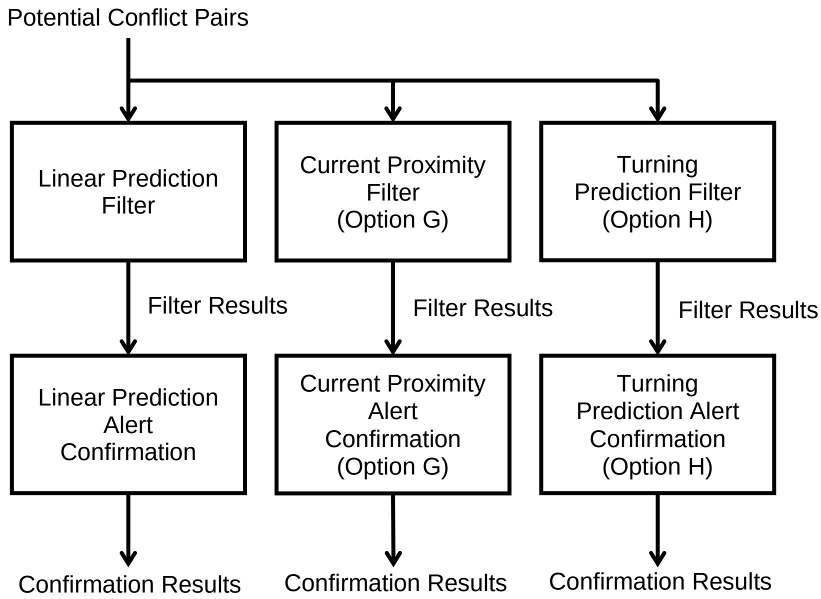


Figure 8: Alert confirmation with multiple filters

2.16.3 Conflict results from the fine filters

The conflict result from each of the fine filters is passed to the corresponding alert confirmation stage. The conflict result is expressed as either a “conflict hit” or a “conflict miss” on the current STCA cycle.

A conflict hit result from a filter does not necessarily mean that an alert will be generated. This is determined by the alert confirmation stage. However, if an STCA conflict is been confirmed from any of the individual alert confirmation processes, then the alert is issued to the display.

2.16.4 Linear prediction alert confirmation

2.16.4.1 Overview

The processing logic of the linear prediction alert confirmation stage is shown in Figure 9.

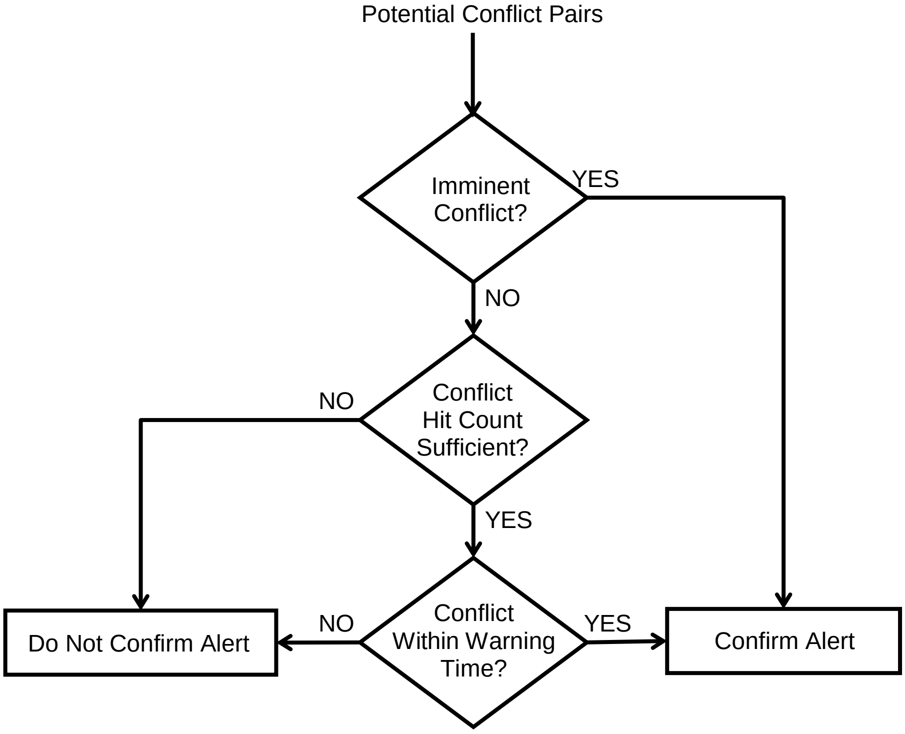


Figure 9: Alert confirmation stage for the linear prediction filter

2.16.4.2 Test for imminent conflict

If a conflict situation is imminent then it is appropriate to bypass the other delay mechanisms and provide an alert on the current cycle. For example, an imminent conflict may be caused by a sudden departure from a level, or a situation may become imminent around the time of a level bust.

The test for an imminent conflict is simply based on the time of violation (TOV) calculated earlier in the linear prediction filter.

If TOV is less than a parameter **LinearPredictionImminentTime[n]**, then an alert is declared immediately. Otherwise further tests are done to see if it is safe to delay the alert.

2.16.4.3 The conflict hit count mechanism (M out of N)

Sometimes tracks can be presented to STCA that are very noisy or are in the process of a heading change during a turn. See Figure 10 for an example of a turning aircraft:

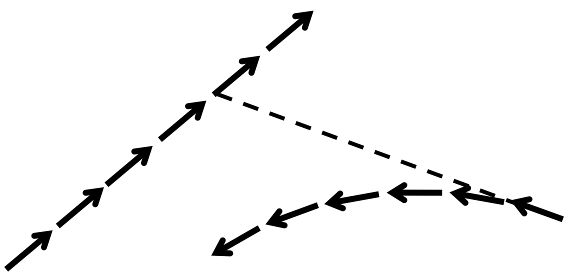


Figure 10: Aircraft apparently in conflict for one or two cycles

In such circumstances, aircraft can wrongly appear to be heading towards each other for one or two cycles.

To avoid nuisance alerts, the alert confirmation stage employs an algorithm that counts the number of conflict hits that have been detected for the track pair over the last few cycles. Furthermore, the mechanism allows continuity of the alert if there is an occasional miss in the sequence of conflict hits from the filter.

In the reference STCA system, it is assumed that the algorithm is implemented using a sliding window to store the last few conflict results. The algorithm considers the filter results over the last N cycles. If the number of conflict hits in the last N cycles reaches a threshold, M, then the conflict count test is passed. (It is sometimes referred to as an M out of N test).

In the linear prediction alert confirmation stage, the thresholds M and N, for declaring an alert, are specified by **LinearPredictionConflictCount[n]** and **LinearPredictionCycleCount[n]**, respectively.

2.16.4.4 Test against time of violation

If the count of conflict hits is sufficient then the situation is examined further to see if an alert is required.

The test to see if an alert is required is simply based on the time of violation (TOV) calculated earlier in the linear prediction filter.

If TOV is less than a parameter **LinearPredictionWarningTime[n]**, then an alert is declared immediately.

However, under option I, a further test is performed before confirming the alert. This test assesses the situation to see if there is time to perform a standard vertical or horizontal manoeuvre. If the test is passed then the alert will be delayed for this conflict cycle.

2.16.4.5 Time for standard manoeuvre test (option I)

The use of warning time parameter **LinearPedictionWarningTime[n]** carries with it the assumption that the amount of time required for the controller(s) and pilot(s) to resolve the conflict is the same in all situations. However, this is unrealistic. In practice, the time required will depend upon the horizontal and vertical characteristics of the situation.

The purpose of the “time for standard manoeuvre” test is to assess whether the situation could be resolved by the controller instigating a standard vertical level off or horizontal manoeuvre. For example, in head-on conflicts, when the aircraft are heading straight for one another, it is unlikely that a standard turning manoeuvre will resolve the conflict.

In this case, STCA should produce an alert. However, if the aircraft are converging at a slower rate (for example, one aircraft slowly catching up with an aircraft in front, or both aircraft near-parallel), it is much more likely that a turning manoeuvre could easily be instigated that would bring the aircraft out of conflict. In this case, the alert may be delayed to see how the situation develops.

The basic principle of the time for standard manoeuvre test is to model an assumed conflict-resolving manoeuvre in reaction to the conflict situation. The model assumes that the controller(s) and pilot(s), plus communications between them will require a certain amount of time, a reaction time, before the aircraft starts to manoeuvre. In the vertical domain, a level off of one or both aircraft is modelled, which may lead to sufficient vertical separation between the aircraft. (Note that the situation is only declared safe if the assumed vertical manoeuvre leads to both aircraft being level and safely separated. No reassessment is made of the vertical violation interval). In the horizontal domain, horizontal turns are modelled, which may provide sufficient horizontal separation. If either manoeuvre provides sufficient (vertical or horizontal) separation then the alert will be delayed on this cycle.

Hence three tests are described below which can delay an alert if there is time for a standard manoeuvre. These are:

- Single level off test
- Double level off test

- Standard horizontal turn test

Note that the level off tests (single and double) are particularly suitable if the CFL level is not used by the STCA system, since they will help to reduce the number of nuisance alerts due to level off type situations.

2.16.4.6 Selection of the appropriate level off test

The single and double level-off tests are appropriate for different types of vertical situation. If one aircraft is climbing and the other is descending, then the double level off test must be performed. The single level off test cannot resolve this type of conflict, because the aircraft will still be converging after the modelled level off. However in all other circumstances (both aircraft climbing, both descending, one aircraft level) the single level off test only must be used.

To clarify, if VZ1 and VZ2 are the vertical rates of the two aircraft, then the double level off test (and not the single level off test) must be used if:

VZ1 x VZ2 < 0

Otherwise, the single level off test (and not the double level off test) must be performed.

2.16.4.7 Single level off test

For this test, a reaction time, trv, is assumed before the level off manoeuvre occurs. This time is given by the STCA parameter **SingleLevelOffReactionTime[n]**.

A single level off manoeuvre will be considered if the time of the vertical violation calculated in the linear prediction filter (TVS) is later than the required reaction time. (There is insufficient time if the vertical violation is already in progress before the controller etc. can react to the conflict).

A level off manoeuvre is considered for each aircraft in turn. The aircraft considered for the manoeuvre must have a non-zero vertical rate and (if available and used in STCA) have no CFL and/or SFL. Note that in these tests the availability of CFL or SFL is determined on an individual aircraft basis. A lack CFL and/or SFL for a particular flight normally indicates that the aircraft is eligible for a level off manoeuvre test.

The single level off manoeuvre is shown Figure 11.

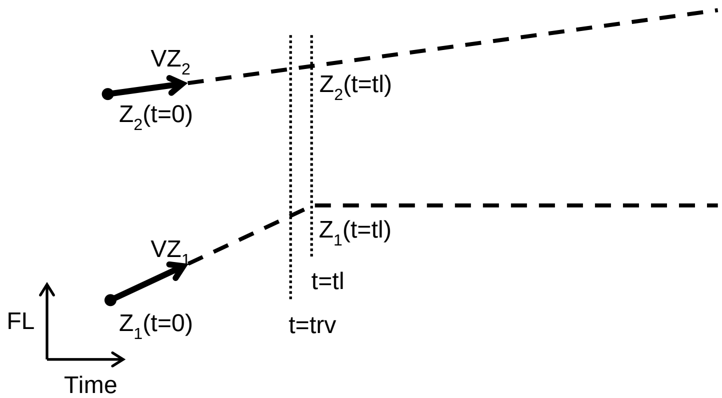


Figure 11: The single level off manoeuvre

In the diagram, the vertical track state for the aircraft is given by Z1, VZ1, Z2 and VZ2. Both aircraft continue at a uniform vertical rate up to time trv. Then, one aircraft levels off at a standard rate of vertical deceleration. The time of level off is denoted by tl.

The vertical manoeuvre is considered safe if the vertical separation between the aircraft at time tl is greater than a parameter **LevelOffVerticalSeparation[n,vsep]**. Additionally, the aircraft must not have crossed vertically during the manoeuvre nor must they be closing vertically at time tl.

In summary, the single level off test is satisfied if all the following conditions are met:

- The track does not have a CFL and/or SFL
- Time to vertical violation TVS > **SingleLevelOffReactionTime[n]**
- The aircraft considered for manoeuvre has a non-zero vertical rate
- At tl, aircraft vertical separation > **LevelOffVerticalSeparation[n,vsep]**
- The aircraft have not crossed vertically during the manoeuvre
- At tl, the aircraft are not closing vertically

The single level off test is done (i.e. the level off is modelled) for each aircraft in turn. If either aircraft satisfies the test then confirmation of the alert is delayed on this conflict cycle.

2.16.4.8 Double level off test

For this test, a different reaction time, trv2 (given by **DoubleLevelOffReactionTime[n]**), is assumed before the actual level off manoeuvre of both aircraft starts. This parameter should be set to a larger value than **SingleLevelOffReactionTime[n]** to account for the longer time required instructing both aircraft to level off.

A double level off manoeuvre will be considered if the time of the vertical violation calculated in the linear prediction filter (TVS) is later than the required reaction time (i.e. there is insufficient time if the vertical violation is already in progress before the controller etc. can react to the conflict). In addition, neither aircraft may have a CFL and/or SFL available and used by STCA. The double level off manoeuvre is shown in Figure 12:

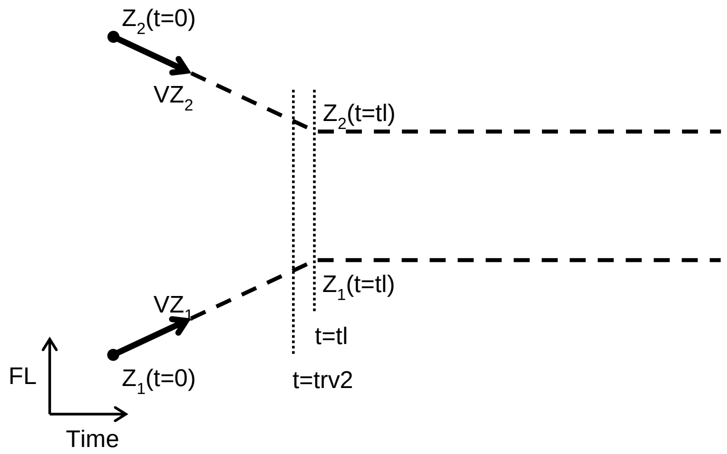


Figure 12: The double level off manoeuvre

In the diagram, the vertical track state for the aircraft is given by Z1, VZ1, Z2 and VZ2. Both aircraft continue at a uniform vertical rate up to time trv2. Then, both aircraft level off at a standard rate of vertical deceleration. The time of level off is denoted by tl.

The vertical manoeuvre is considered safe if the vertical separation between the aircraft at time tl is greater than a parameter **LevelOffVerticalSeparation[n,vsep]**. Additionally, the aircraft must not have crossed vertically during the manoeuvre.

In summary, the double level off test is satisfied if all the following conditions are met:

- Neither track has a CFL and/or SFL available and used by STCA
- Time to vertical violation TVS > **DoubleLevelOffReactionTime[n]**
- At tl, aircraft vertical separation > **LevelOffVerticalSeparation[n,vsep]**
- The aircraft have not crossed vertically during the manoeuvre

If the double level off test is satisfied confirmation of the alert is delayed on this conflict cycle.

2.16.4.9 Standard horizontal turn test

For the standard horizontal turn test, it is assumed that both aircraft will continue on their present headings for a reaction time given by trl.

Standard horizontal turns will be considered if the time of the horizontal violation THS, calculated by the linear prediction filter occurs after the reaction time period trl.

A standard horizontal turn situation is illustrated in Figure 13.

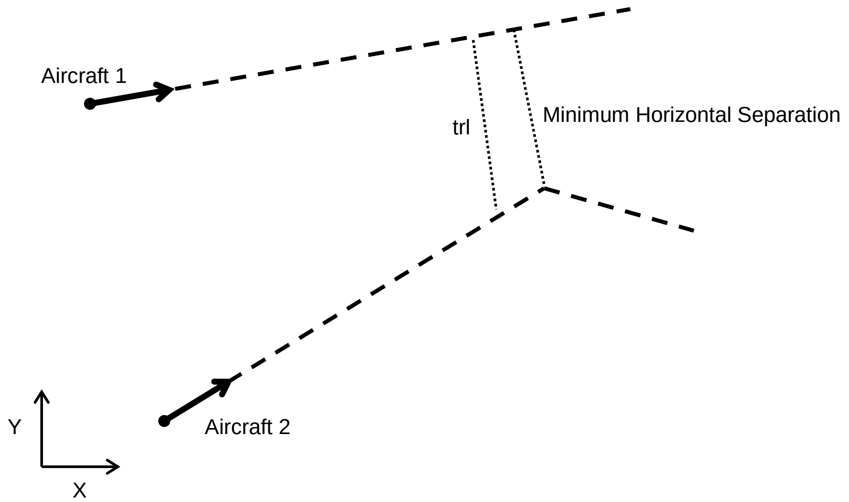


Figure 13: A standard horizontal turn

Each turn is modelled assuming some standard turn rate. The position of the aircraft is computed in a step-wise fashion, and the horizontal separation calculated on each step. The minimum horizontal separation is computed for each of the four cases described above.

If any of the manoeuvres achieves sufficient minimum horizontal separation then the test is fulfilled and the confirmation of the alert may be delayed on this conflict cycle.

2.16.5 Current proximity alert confirmation (part of option G)

2.16.5.1 Processing logic

The processing logic of the current proximity alert confirmation stage is shown in Figure 14.

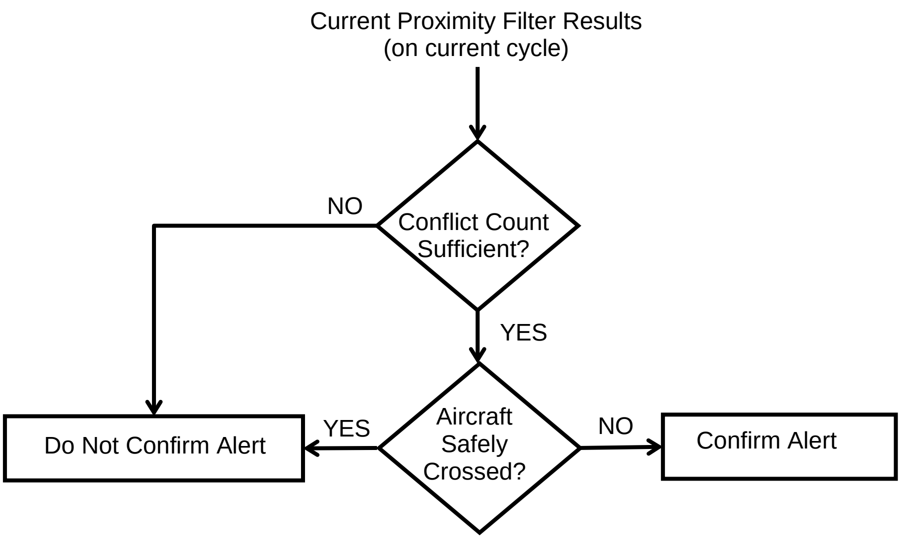


Figure 14: Alert confirmation stage for the current proximity filter

2.16.5.2 Counting conflict hits to confirm alerts

The alert confirmation stage employs the same conflict hit counting mechanism as is used in the linear prediction alert confirmation stage.

In the current proximity alert confirmation stage, the thresholds M and N, for declaring an alert are specified by **CurrentProximityConflictCount[n]** and **CurrentProximityCycleCount[n]**, respectively.

If the number of conflict hits is less than **CurrentProximityConflictCount[n]**, then a current proximity alert is rejected on this cycle, otherwise an additional test may be done (under option J) to see if the tracks have already crossed safely.

Otherwise, if the safe crossing test is not employed then the alert will be confirmed if the number of conflict hits is sufficient.

2.16.5.3 Safe crossing test (option J)

In some circumstances, unwanted alerts can arise after the aircraft have crossed horizontally, yet the aircraft are still within the current proximity filter horizontal and vertical thresholds. This may be considered by the controller as a relatively safe situation that may not warrant an alert.

The safe crossing situation is illustrated in Figure 15.

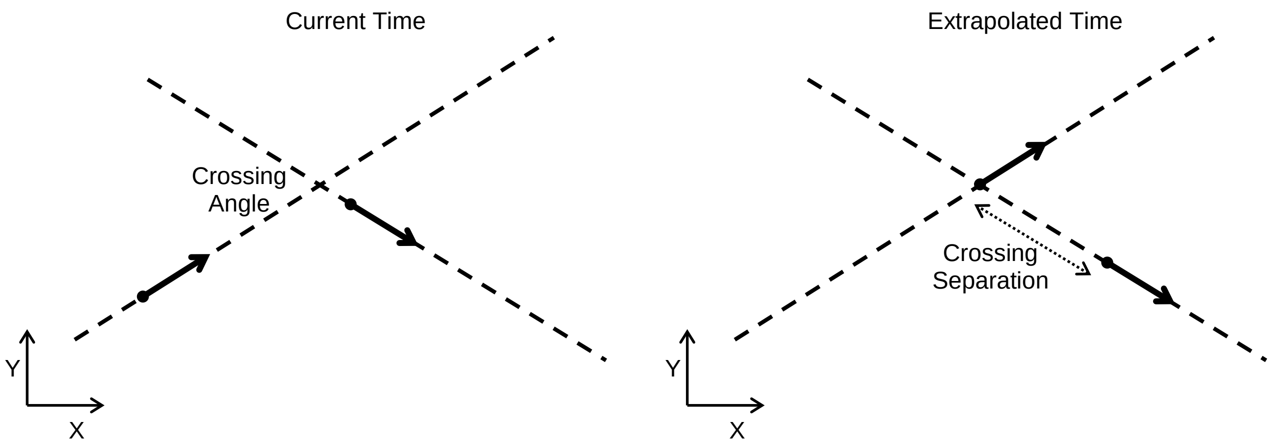


Figure 15: Safe crossing situation

The left-hand diagram shows the situation at the current time, when the first aircraft has already passed the crossing point. The situation is then considered at the extrapolated time, the time at which the second aircraft reaches the crossing point. If the first aircraft has made sufficient distance by this time, then the crossing is considered to be safe.

The calculation of the crossing point is simply done from the equations of two straight lines. However, under some conditions, the calculation can be ill conditioned (i.e. sensitive to small errors or instability in the tracks). Hence, tests are done firstly to ensure that the speed and angle of the tracks are sufficient to prevent any ill conditioning of the crossing point calculation.

A track pair is considered to have made a safe crossing when all the following conditions (tested against suitable thresholds) apply:

- Both aircraft have sufficient speed for a well-conditioned calculation
- The angle of crossing is acceptable
- The crossing point has been reached by at least one of the aircraft
- The separation at the crossing point is sufficient i.e. at least as much as STCA parameter **CurrentProximitySafeHorizontalSeparation[n]**

If all of the above safe crossing conditions are passed, then an alert is not confirmed from the current proximity filter on this cycle.

2.16.6 Turning prediction alert confirmation (part of option H)

2.16.6.1 Processing logic

The processing logic of the turning prediction alert confirmation stage is shown Figure 16.

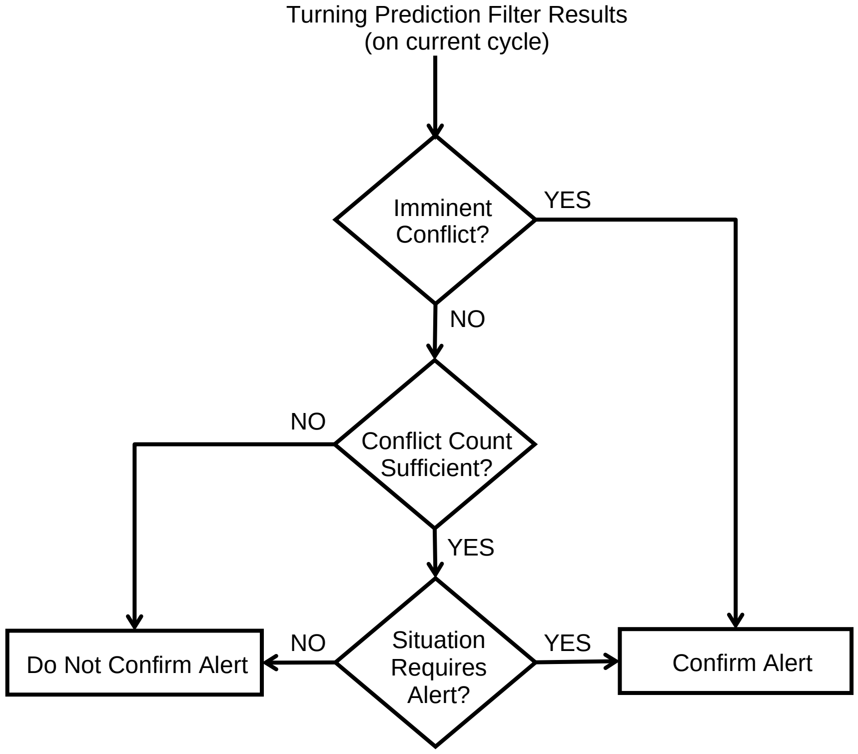


Figure 16: Alert confirmation stage for the turning proximity filter

2.16.6.2 Test for imminent conflict

If a conflict situation is imminent then it is appropriate to bypass the other delay mechanisms and provide an alert on the current cycle.

The test for an imminent conflict is simply based on the time of violation (TPTOV) calculated earlier in the turning prediction filter.

If TPTOV is less than a parameter **TurningPredictionImminentTime[n]**, then an alert is declared immediately. Otherwise further tests are done to see if it is safe to delay the alert.

2.16.6.3 Counting conflict hits to confirm alerts

The alert confirmation stage employs the same conflict hit counting mechanism as is used in the linear prediction alert confirmation stage.

In the turning prediction alert confirmation stage, the thresholds M and N, for declaring an alert are specified by **TurningPredictionConflictCount[n]** and **TurningPredictionCycleCount[n]**, respectively.

If the number of conflict hits is less than **TurningPredictionConflictCount[n]**, then the alert is rejected on this cycle, otherwise further consideration is given in the alert confirmation stage.

2.16.6.4 Test if alert is required

If the count of conflict hits is sufficient then further examination of the situation is done.

The test to see if an alert is required is simply based on the time of violation (TPTOV) calculated earlier in the turning prediction filter.

If TPTOV is less than a parameter **TurningPredictionWarningTime[n]**, then an alert is declared on this cycle.

2.17 Multiple hypotheses (option K)

STCA alerting performance can be significantly improved by performing conflict detection using multiple hypotheses about the aircraft trajectories.

The multiple hypotheses concept is best explained using an example:

- An aircraft is descending towards a CFL that is known to STCA
- The first hypothesis is that the aircraft will level off at the CFL as expected; conflict detection for this hypothesis, the most likely outcome, is optimized for optimal warning time (wider parameter values)
- The second hypothesis is that the aircraft will bust the CFL; conflict detection for this hypothesis, an unlikely outcome, is optimized for suppression of nuisance alerts (narrower parameter values)

The above example illustrates the use of multiple hypotheses to achieve a good compromise between using CFL and choosing to ignore it completely. However, this is achieved at the expense of doubling the required optimization effort.

Multiple hypotheses is not limited to vertical prediction but can in principle be used for any of the conflict detection concepts described in this chapter.

3. Guidance to appropriate STCA parameter values

3.1 Introduction

The purpose of this section is to provide guidance as to which parameter values are likely to give better performance than other ones. Even without using performance measurement of STCA, the effect of some parameter values is easy to see.

The purpose of each of the parameters (defined in chapter 2) is identified. In addition, the most appropriate parameters to modify in a number of different mid-air situations are identified and the risks associated with certain “poor” parameter choices are highlighted.

The guidelines in this section should not be used as a substitute for a proper STCA parameter optimization process. They are intended to offer a head start for those without such a process, so that STCA may be used immediately, and some of the known pitfalls can be avoided. In any circumstances, a full STCA parameter optimization should be undertaken as soon as reasonably practicable.

Note that the following ATC separation rules are assumed in each type of airspace:

Table 3: ATC separation rules in various types of airspace

Airspace	ATC Horizontal Separation	ATC Vertical Separation
En route	5 NM	1 000 ft or 2 000 ft
TMA	3 NM	1 000 ft only

For some parameters, a range of values is suggested. In these cases, the values appropriate for less busy airspace are indicated by being underlined. These values will tend to provide more warning time, but would give a higher nuisance alert rate in busier airspace. When testing STCA performance, it may be appropriate to start with the “less busy” parameter values, and to progress towards the “more busy” values if the nuisance alert rate is considered too high.

It is not necessary to be restricted to the quoted parameter ranges, especially if the parameter optimization process indicates that other values give a better STCA performance. The ATS provider is free to choose wider parameters in order to achieve more warning time, whilst accepting the alert rate penalty. Furthermore, wider parameter values may be generally appropriate if the airspace is particularly quiet, or the traffic is predictable.

The use of CFL will significantly reduce the alert rate. Therefore, if the CFL is used in STCA, then this may also allow the parameters to be extended slightly beyond the quoted ranges.

3.2 Separation level parameters

LowerSeparationFlightLevel
UpperSeparationFlightLevel

These parameters are perhaps the simplest to set for STCA. These are essentially the thresholds at which the vertical separation rules can change (1 000 ft vertical separation below **LowerSeparationFlightLevel** etc.). Typical values for these parameters are:

LowerSeparationFlightLevel = 29 300 ft

UpperSeparationFlightLevel = 41 300 ft

Note that depending on the precise rules over STCA region priority, it may be appropriate to set these values to 28 700 ft and 40 700 ft respectively.

Here, the values are slightly above 29 000 ft and 41 000 ft to allow some tolerance for normal mode C fluctuation for aircraft that are flying nominally level at the vertical boundary (i.e. maintaining FL290 or FL410).

3.3 Coarse filter parameters

CoarseFilterPredictionTime
CoarseFilterHorizontalSeparation
CoarseFilterVerticalSeparation[vsep]

In an STCA system, the coarse filter parameters should be set wide enough to ensure that no track pairs are eliminated that could come into conflict in the next two minutes. If the parameters are sufficiently wide, the coarse filter processing will have no effect on the alerting performance of the STCA system.

CoarseFilterPredictionTime must be set to a value at least as great as any of the other prediction or warning time parameters in STCA. A value of 120 s is sufficient.

CoarseFilterHorizontalSeparation must be at least as large as the ATC separation standard in the airspace to which it applies. It is recommended that values be in the range of 5 NM to 8 NM. Where the traffic density is low, 8 NM will suffice. However, in busier airspace the parameter may need to be lowered in order to reduce the computer loading (i.e. reduce the number of pairs that are processed by the fine filters).

It is recommended that **CoarseFilterVerticalSeparation[vsep]** is set to the applicable vertical ATC separation standard. That is:

CoarseFilterVerticalSeparation[2000] = 2 000 ft

CoarseFilterVerticalSeparation[1000] = 1 000 ft

3.4 Fast diverging conditions

HorizontalFastDivergingVelocity[n]
HorizontalFastDivergingSeparation[n]
VerticalFastDivergingVelocity[n]
VerticalFastDivergingSeparation[n,vsep]

The parameter values for the fast diverging conditions are not critical for warning time performance. They could take the following ranges of values:

HorizontalFastDivergingVelocity[n] = 100 to 200 knots.

VerticalFastDivergingVelocity[n] = 500 to 1 000 ft/min

The minimum separation parameters would normally be set somewhat below the linear prediction and current proximity separation parameters. The following ranges of values are suggested:

Table 4: Recommended parameter values for fast diverging conditions

Parameter	**Unit**	**En route**	**TMA**
HorizontalFastDivergingSeparation[n]	NM	1.5 – 2.5	1.0 – 1.5
VerticalFastDivergingSeparation[n,1000]	ft	400 – 650	400 – 650
VerticalFastDivergingSeparation[n,2000]	ft	1 300 – 1 600	Not relevant for TMA

3.5 The use of CFL, SFL and BFL

UseCFLFlag[n]
UseSFLFlag[n]
UseBFLFlag[n]

In some STCA systems the CFL and/or SFL or BFL are used by STCA. In essence, there is no practical difference between the effect of CFL, SFL and BFL on STCA performance. The use of any of these data items in STCA increases the relevance of conflict prediction. However, the use of CFL in STCA should only be considered if the controller is required to systematically input CFL for other purposes. A user-friendly HMI should be provided to facilitate those inputs.

Furthermore, the use of the CFL (or BFL) must be considered carefully by the ATS provider, since there are inherent advantages and disadvantages to using it.

The advantages are:

- It considerably reduces the nuisance alert rate, especially the frequently occurring level-off type of situations (depending on its operational use, the STCA parameter values and traffic density, up to 90% reduction in the alert rate may be achieved)
- STCA will generally provide more warning time in the event where two aircraft are cleared to the same flight level (depending on the horizontal geometry)
- The reduction in the nuisance alert rate may allow the user to set wider horizontal, vertical and prediction time parameters, further increasing the achievable warning time

The disadvantages are:

- There will be very little warning time if the controller inputs a CFL, but the aircraft busts through the level. In these circumstances, conflicts are alerted only after the level bust

  Note: It is possible to define a level band above/below the CFL where, if the aircraft is maintaining a high vertical rate within this level band, the CFL will no longer be used for prediction in order to provide early warning for aircraft that will not level off at their CFL

- The CFL may be input inaccurately or may not be updated by the controller, which could, depending on the circumstances, delay a wanted alert

Not using the CFL also has certain advantages and disadvantages. The advantages are:

- In the event of a level bust, it will be possible for STCA to alert before the level bust occurs
- The controller will be aware of a potentially hazardous situation arising, if the aircraft were not to adhere to the cleared level

The disadvantages are:

- The alert rate is likely to be relatively high. (Although alert confirmation mechanisms like the vertical level off tests can help to reduce this problem)
- It may be necessary to restrict the STCA parameters (particularly the horizontal, vertical and prediction time parameters) in order to achieve an acceptable alert rate

Because of these advantages and disadvantages, it is not possible in this manual to recommend either use, or non-use of the CFL.

If the SFL is available down-linked from the aircraft, then this may be favourable for use because it will overcome much many of the inherent disadvantage of using a controller input CFL. Furthermore, it is possible in the ATM system to check the input CFL against the down-linked SFL and indicate any inconsistency to the controller.

In the event that the CFL is used in STCA, it is recommended that:

- For consistent STCA behaviour, the CFL is applied in all STCA regions (not just in some regions)
- The controller is aware of the importance of inputting a consistent and accurate CFL into the system
- The STCA system is configured to alert as soon as a level bust occurs
- The controller is familiar with the STCA vertical prediction mechanism

Ultimately, the use of the CFL in the STCA system is up to the ATS provider. The effects of the use of CFL in STCA should be fully considered in the safety case. The inherent advantages must be weighed against the disadvantages and a decision made.

3.6 Linear prediction filter parameters

LinearPredictionTime[n]
LinearPredictionHorizontalSeparation[n]
LinearPredictionHorizontalSeparationDiverging[n]
LinearPredictionVerticalSeparation[n,vsep]

Initially, it is tempting for many ATS provider's to set the separation parameters to the ATC separation standard (3 NM or 5 NM and 1 000 ft or 2 000 ft, depending on airspace). This may be appropriate if the traffic density is very low, or otherwise there is a tolerable number of nuisance alerts. Nevertheless, there are a number of good arguments for setting the parameters to less than the ATC separation standard.

In most STCA systems, the linear prediction separation parameters will have a profound effect on the alert rate.

LinearPredictionHorizontalSeparation[n], in particular if set too high, is likely to result in an unnecessarily high nuisance alert rate.

Figure 17 shows the typical alert rates in en route airspace against the parameter **LinearPredictionHorizontalSeparation[n]**.

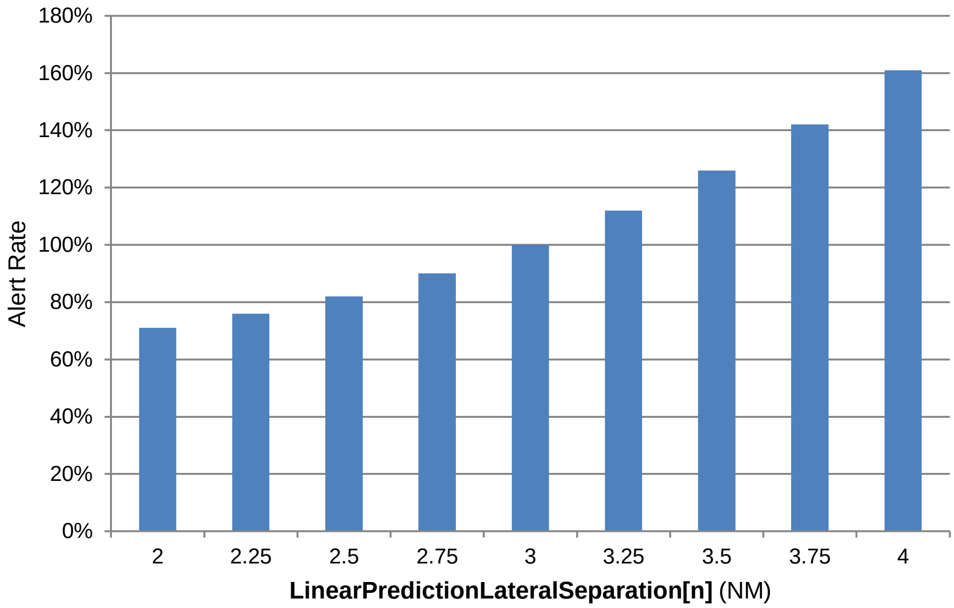


Figure 17: Increase of alert rate with LinearPredictionLateralSeparation[n]

It is quite common to have circumstances like the example below where two aircraft appear to be heading towards each other. This is why the alert rate increases with the horizontal separation parameter. If just one of the aircraft is turning slowly away from the other aircraft, the reality can turn out very different from the linear prediction. See Figure 18.

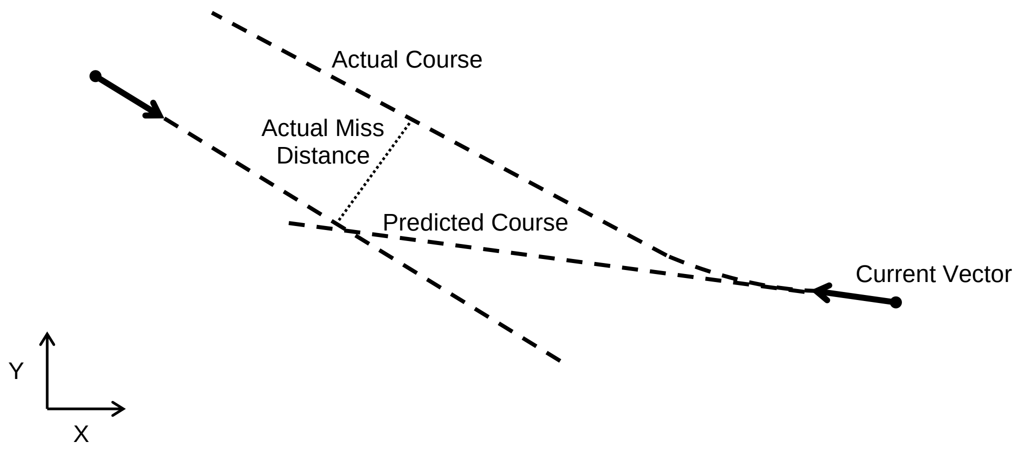


Figure 18: Situation showing the inaccuracy of linear prediction in presence of subtle turns

Simplistic diagrams showing STCA alerts occurring between aircraft on perfectly straight courses are largely misrepresentative of typical traffic, especially traffic in the TMA. In reality, aircraft may be turning or even have small fluctuations in the heading that will have a significant effect on the calculated horizontal miss distance. The same holds true in the vertical dimension. Pictures of actual vertical climbs and descents show that the aircraft vertical rate often fluctuates during the course of the climb or descent.

In actual fact, the error in the predicted future position of the aircraft has two sources:

- The error in the assumed linear motion of the aircraft (because aircraft may turn or change their vertical rates in the future)
- The error in the current 3D state vector from imperfect surveillance and tracking

From these simple facts, we can conclude two things:

- There are limits to the accuracy of a conflict predicted by STCA
- Improvements to the accuracy of the system tracks will help improve STCA performance, but the effect will to be somewhat limited

In STCA systems where there is no use of the CFL and/or SFL, the most common situation where alerts occur is the level-off situation when one aircraft levels off at a flight level 1 000 ft separated from another aircraft. See Figure 19.

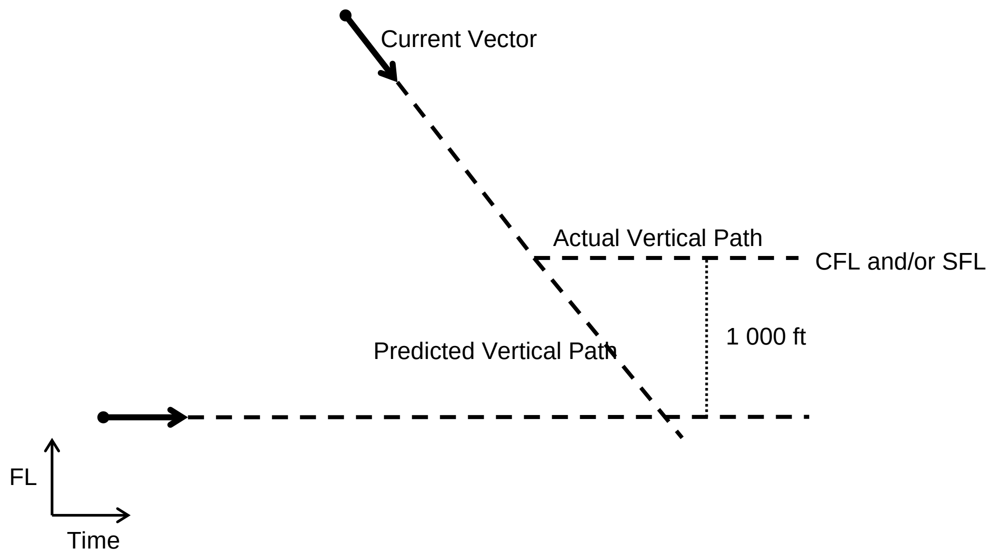


Figure 19: The level off situation

This may be a nuisance to the controller who has already cleared the aircraft to a safe flight level. In such situations the alert rate will depend largely on the horizontal separation parameters. If wide parameter values are set, then the alert rate may be intolerable.

Therefore, it is recommended that when no CFL are used, the ATS provider should consider setting the horizontal separation parameters to values somewhat less than the applied ATC separation rules. These parameters, being STCA region dependent, can easily be set to the values appropriate for the specific airspace.

Nevertheless, it is true that in some circumstances, particularly where one aircraft is turning towards another into conflict, using narrower parameters will result in a shorter warning time, The temptation for the ATS provider is to widen the horizontal separation parameters in order to catch the alert earlier. However, a much more appropriate solution would be to keep the linear prediction filter parameters below the ATC separation standard, and to use a turning prediction filter to generate an earlier warning.

To help understand the various deciding factors, some example values for **LinearPredictionHorizontalSeparation** (in en route airspace) in different circumstances are given in Table 5.

Table 5: Example values for LinearPredictionLateralSeparation in en route airspace

	Quiet Airspace, or traffic flying in predictable straight courses	**Busy Airspace or less predictable traffic**
CFL and/or SFL used by STCA, no turning prediction	4.5 NM	4 NM
CFL and/or SFL used by STCA, turning prediction	4.5 NM	3.5 NM
CFL and/or SFL not used by STCA, no turning prediction	3.5 NM	3 NM
CFL and/or SFL not used by STCA, turning prediction	3.5 NM	2.5 NM

Progressing now to the vertical dimension, most aircraft fly exactly on their assigned flight level. However, sometimes aircraft can be seen flying nominally level, but 100 or 200 ft off the flight level. Therefore, it is recommended that **LinearPredictionVerticalSeparation[n,vsep]** be set sufficiently below the applied ATC vertical separation standard, in order to avoid excessive nuisance alerts, for example to 700 ft and 1 700 ft.

In a fully tuned STCA system, the value of **LinearPredictionTime[n]** is not critical, since the timing of the alert (and alert rate) will be determined by the following parameters in the alert confirmation stage:

- **LinearPredictionImminentTime[n]**
- **LinearPedictionWarningTime[n]**
- “time for standard manoeuvre” parameters

It is recognized that some STCA systems do not have separate prediction time and warning time parameters. In this case, the duration of the prediction is critical in achieving the right balance between warning time and nuisance alert rate.

However, in most STCA systems **LinearPredictionTime[n]** simply needs to be high enough to allow sufficient conflict hits to have built up by the time the alert could pass the alert confirmation stage. (Perhaps 20 to 30 s greater than the longest time limit parameter in the alert confirmation stage).

The optimal values will, to some extent depend on the traffic levels and the other features of the STCA system, but the following ranges of values are recommended for average to busy airspace:

Table 6: Recommended parameter values for the linear prediction filter

Parameter	**Unit**	**En route**	**TMA**
LinearPredictionTime[n]	s	80 – 120	80 – 120
LinearPredictionHorizontalSeparation[n]	NM	2.5 – 4.5	2.0 – 2.75
LinearPredictionHorizontalSeparationDiverging[n]	NM	1.75 – 3.0	1.5 – 2.0
LinearPredictionVerticalSeparation[n,1000]	ft	500 – 750	500 – 750
LinearPredictionVerticalSeparation[n,2000]	ft	1500 – 1 750	Not relevant for TMA

3.7 Current proximity filter parameters

CurrentProximityHorizontalSeparation[n]
CurrentProximityVerticalSeparation[n,vsep]

It is appropriate to set the current proximity parameters to values somewhere between the equivalent linear prediction parameters and the ATC separation standard, thus giving the filter the potential to provide STCA alerts before the linear prediction filter in some situations.

The following ranges of values are recommended:

Table 7: Recommended parameter values for the current proximity filter

Parameter	**Unit**	**En route**	**TMA**
CurrentProximityHorizontalSeparation[n]	NM	3.0 – 4.75	2.0 – 2.85
CurrentProximityVerticalSeparation[n,1000]	ft	700 – 800	700 – 800
CurrentProximityVerticalSeparation[n,2000]	ft	1700 – 1 800	Not relevant for TMA

3.8 Turning prediction filter parameters

TurningPredictionTime[n]
TurningPredictionHorizontalSeparation[n]

The turning prediction filter uses turn related information from the system track to do its prediction. The parameters values chosen may well depend upon the accuracy of the tracker's turn detection algorithm. If the tracker provides the turn rate then this should be used in the prediction. Otherwise a standard turn rate may be assumed.

Recommended parameter value ranges are shown in Table 8:

Table 8: Recommended parameter values for the turning prediction filter

Parameter	**Unit**	**En route**	**TMA**
TurningPredictionHorizontalSeparation[n]	NM	3.0 – 4.0	1.5 – 2.5
TurningPredictionTime[n]	s	70 – 90	70 – 90

It is recommended to keep the **TurningPredictionHorizontalSeparation[n]** parameter below the ATC separation standard in order to reduce the number of nuisance alerts.

The value of **TurningPredictionTime[n]** is not critical, since the timing of the alert will be determined by the parameters in the alert confirmation stage. Assuming that **CoarseFilterPredictionTime[n]** is set to 120 s and appropriate tuning is done in the alert confirmation stage, a value of between 70 s and 90 s is recommended for **TurningPredictionTime[n]**, in all STCA regions.

If the turn rate is not available from in the input system tracks, then a turn rate must be assumed. Although the standard ATC "rate 1" turn is at 3o/s, actual measurements of turning aircraft have shown mean turn rates to be closer to 2o/s. In any airspace, it is recommended to measure the actual mean turn rates of aircraft undergoing turns, and set the modelled turn rate in STCA accordingly.

3.9 Linear prediction basic alert confirmation parameters

LinearPredictionImminentTime[n]
LinearPredictionConflictCount[n]
LinearPredictionCycleCount[n]
LinearPedictionWarningTime[n]

The Linear prediction alert confirmation parameters are used to provide STCA alerts at the appropriate time. If there is plenty of time until violation, then the alert may be delayed to see how the situation develops. (Many conflict situations resolve themselves without the need for further controller intervention).

If the infringement of the separation parameters is imminent then the alert should be provided immediately.

The following parameter ranges are recommended for the linear prediction imminent time and warning time parameters. Any less than these and there is a risk that the controller(s) and pilot(s) will not have sufficient time to resolve the situation.

Table 9: Recommend values for the basic linear prediction alert confirmation parameters

Parameter	Unit	En route	TMA
LinearPedictionWarningTime[n]	s	50 - 90	50 – 80
LinearPredictionImminentTime[n]	s	35 - 50	35 – 50

If the times for standard manoeuvre tests are used (under option I) then these should be used in preference to the **LinearPedictionWarningTime[n]** test. The standard manoeuvre tests are far more sophisticated and are likely to give better STCA performance results.

The purpose of the linear prediction conflict count is to suppress STCA alerts in transitory situations or where the track data is noisy or jumpy. See Figure 20.

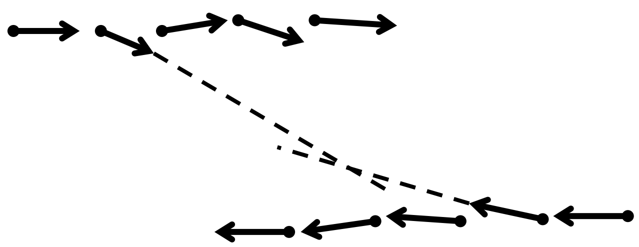


Figure 20: Noisy tracks giving rise to an STCA alert

The diagram shows two aircraft, one of which has noisy track data giving rise to an STCA alert. The conflict hit count mechanism suppresses such nuisance alerts by requiring a conflict to be detected on more than one cycle before confirming the alert.

Typically, the conflict count parameters should take the following values:

LinearPredictionConflictCount[n] = <u>2</u> or 3

LinearPredictionCycleCount[n] = <u>4</u> or 5

Using higher values of (maybe in an attempt to reduce the nuisance alert rate) is not appropriate because excessive delays in alerts will occur.

For **LinearPredictionConflictCount[n]** a value of 3 has generally been shown to give a good result, suppressing nuisance alerts, yet not delaying wanted alerts too much.

Using a value of 2 for **LinearPredictionConflictCount[n]** will increase the nuisance alert rate but may be appropriate for airspace where there is good surveillance coverage and the available warning time is frequently more limited (e.g. in holding areas).

Consider the departure from level situation in Figure 21.

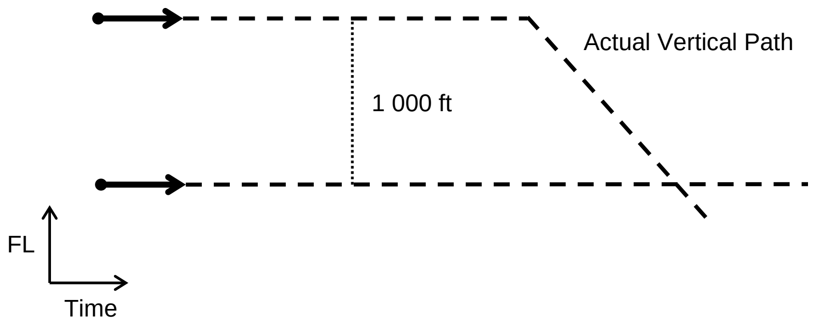


Figure 21: A departure from flight level situation

Here, an apparently safe situation can rapidly develop into a serious conflict situation. (A similar situation could be imagined in the horizontal dimension with turning aircraft). It is imperative that STCA produces an alert quickly for this type of situation. A high conflict count value (say 4 or 5) will delay the alert unnecessarily. For example if the conflict cycle period was 4 s, it could delay the alert by up to 20 or 25 s.

Additionally, a useful mechanism, in some STCA systems, is to bypass the conflict count requirement entirely if the aircraft are vertically very close and converging.

3.10 Time for standard manoeuvre parameters

SingleLevelOffReactionTime[n]
LevelOffDecelerationRate[n]
LevelOffVerticalSeparation[n,vsep]
DoubleLevelOffReactionTime[n]
StandardTurnReactionTime[n]
StandardTurnRate[n]
StandardTurnHorizontalSeparation[n]

The time for standard manoeuvre tests provide an effective means of reducing the nuisance alert rate, and are particularly useful when the CFL is not available.

The reaction time parameters (**SingleLevelOffReactionTime[n]**, **DoubleLevelOffReactionTime[n]** and **StandardTurnReactionTime[n]**) are supposed to cover the reaction times of the controller, communications, and also pilot and aircraft reaction. The appropriate reaction times are highly subjective, and ultimately these may have to be reduced, particularly in the TMA in order to prevent too many nuisance alerts. Suggested values for these parameters are given below.

Table 10: Recommended values for the standard manoeuvre reaction time parameters

Parameter	**Unit**	**En route**	**TMA**
SingleLevelOffReactionTime[n]	s	50 – 70	50 – 70
DoubleLevelOffReactionTime[n]	s	60 – 80	60 – 80
StandardTurnReactionTime[n]	s	50 – 70	50 – 70

The required separation parameters (**LevelOffVerticalSeparation[n,vsep]** and **StandardTurnHorizontalSeparation[n])** should be set to values which give adequate assurance that the manoeuvre will provide sufficient separation. However, the values may need to be adjusted (along with the reaction time parameters) to achieve the desired balance between alert rate and warning time performance.

Suggested parameter ranges are given below.

Table 11: Recommended values for the standard manoeuvre separation parameters

Parameter	Unit	En route	TMA
LevelOffVerticalSeparation[n,1000]	ft	500 - 700	500 – 700
LevelOffVerticalSeparation[n,2000]	ft	1 500 – 1 600	Not relevant
StandardTurnHorizontalSeparation[n]	NM	2.0 – 3.0	1.5 – 2.0

3.11 Current proximity basic alert confirmation parameters

CurrentProximityConflictCount[n]
CurrentProximityCycleCount[n]

CurrentProximityConflictCount[n] and **CurrentProximityCycleCount[n]** provide the means to avoid nuisance alerts generated by the occasional noisy track update, whilst allowing some continuity of the alert in the event of the occasional conflict miss.

Because of the nature of current proximity conflicts, it is imperative that the alert is not delayed unnecessarily. Therefore a small value of **CurrentProximityConflictCount[n]** = 2 is recommended. To allow for some alert continuity, **CurrentProximityCycleCount[n]** should be set to 3.

3.12 Safe crossing parameter

CurrentProximitySafeHorizontalSeparation[n]

CurrentProximitySafeHorizontalSeparation[n], the minimum safe crossing distance should be set to a value less than the current proximity separation, **CurrentProximityHorizontalSeparation[n]**, otherwise the safe crossing test will only rarely be satisfied.

To satisfy the safe crossing test, at least one of the aircraft must have passed the crossing point, thus the perceived risk of collision is already less than would have been if the aircraft had not crossed. If the separation is sufficient when the second aircraft passes the crossing point, then the situation is declared safe, and no alert is issued (from the current proximity filter) on this cycle. The exact distance that represents a safe crossing is open to debate. However, here are some suggested ranges of values:

Table 12: Recommend parameter values for safe horizontal crossing

Parameter	Unit	En route	TMA
CurrentProximitySafeHorizontalSeparation[n]	NM	2.0 – 4.0	1.0 – 2.5

3.13 Turning prediction alert confirmation parameters

TurningPredictionImminentTime[n]
TurningPredictionConflictCount[n]
TurningPredictionCycleCount[n]

TurningPredictionWarningTime[n]

The turning prediction filter relies on having stable and accurate turn information from the surveillance data processing. However, noisy plot data can sometimes result in unreliable and inaccurate tracking, particularly with regard to the turn rate. Therefore it is important to be able to provide the alert with continuity over one or two conflict misses.

An additional consideration is the fact that a situation in which aircraft are turning can rapidly deteriorate from a potential risk to a very high risk of collision. Therefore, it is also essential to be able to provide the alert fairly quickly when the turning prediction filter has detected a conflict.

With these points in mind, the following values are recommended in all areas of airspace:

TurningPredictionConflictCount[n] = 2

TurningPredictionCycleCount[n] = 4

The value of 2 for **TurningPredictionConflictCount[n]** should provide a rapid response to a potential turn into conflict. The value of 4 for **TurningPredictionCycleCount[n]** will allow STCA to continue the alert for up to two cycles, when the turning prediction filter may not have detected the alert due to unstable turn information in the track data.

The turning prediction alert confirmation parameters are used to provide STCA alerts at the appropriate time. If there is plenty of time until violation occurs, then the alert may be delayed to see how the situation develops. (Many conflict situations resolve themselves without the need for further controller intervention).

If the infringement of the separation parameters is imminent then the alert should be provided immediately.

The following parameter ranges are recommended for the imminent time and warning time parameters. Any less than these and there is a risk that the controller(s) and pilot(s) will have insufficient time to resolve the situation.

Table 13: Recommended values for the turning prediction alert confirmation parameters

Parameter	**Unit**	**En route**	**TMA**
TurningPredictionWarningTime[n]	s	50 – <u>70</u>	50 – <u>70</u>
TurningPredictionImminentTime[n]	s	35 – <u>50</u>	35 – <u>50</u>

4. Optimisation concepts

4.1 Introduction

STCA 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.

4.2 Analysis team composition

It is vital that the analysis and optimisation of STCA performance is undertaken by a team that 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.

4.3 Scenario categorisation

4.3.1 Introduction

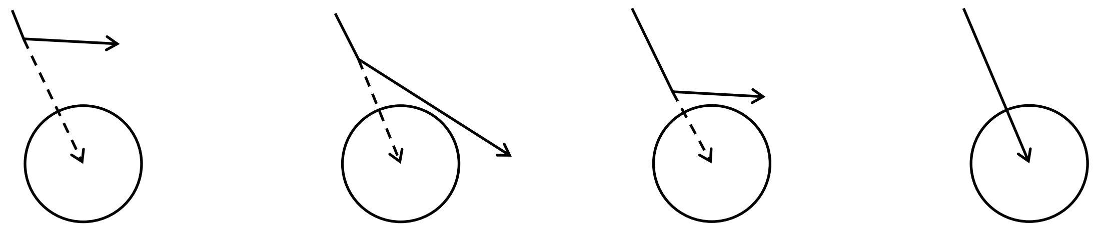
STCA performance is measured by the numbers of genuine and nuisance alerts which are displayed to controllers, together with the amount of warning time provided for genuine alerts. Before these items can be measured, the STCA analysts need to know which scenarios should have been alerted and which should 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

Figure 22 illustrates some sample categories (horizontal view where the circle represents the horizontal separation threshold).



Category 3

Alert “understandable” but unnecessary

Category 2

Alert “desirable” but situation dealt with by “standard maneuver”

Category 1

Situation dealt with by “late maneuver”

Category 1

Situation not dealt with

Figure 22: Sample STCA categories

Using these categories, the theoretical aim of STCA 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 STCA occasionally alerting Category 5 scenarios, either by system adaptation or algorithm design.

4.3.2 Separation standards

If the minimum achieved distance is used in determining the Category of a scenario, the applicable separation standard may be relevant since this indicates the minimum official permitted distance. For example, a minimum achieved lateral distance between two aircraft of 4NM in a region where the separation standard is 10NM may be considered to be more severe than an achieved distance of 2NM in a region where the separation standard is 3NM (2/5 separation standard as opposed to 2/3).

4.3.3 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 collisions and losses of separation, plus those scenarios where such a situation 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.

The precise definition assigned to “serious loss of separation” (and hence the appropriate parameter settings) is dependent on the individual circumstances surrounding each implementation. A quantified definition is therefore inappropriate to an international document such as this, since the necessary coordination work has not yet been undertaken.

4.3.4 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 a standard manoeuvre. It is therefore not necessary for official ATC separation to be breached for a scenario to be Category 2.

A situation likely to cause a Category 2 scenario is where a descending aircraft is about to level off but no CFL and/or SFL information is available. The predicted path during the descent may indicate a potential hazard, and thus generate an alert, even though the aircraft's intended route is perfectly acceptable. In certain circumstances, failing to level off at the appropriate level could put the aircraft at risk, hence the perception in some organisations that such scenarios should be alerted.

4.3.5 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 scenarios are generally situations similar to those discussed under Category 2 without the element of risk. Negligible losses of separation may, in certain situations, be considered to be Category 3.

4.3.6 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 aircraft carrying out standard operations where, for a short period of time the aircraft's predicted path(s) results in a predicted hazard within the specified look ahead time but would not be of any concern from the controller's point of view.

There may also be scenarios where the analysis display does not suggest how a conflict could be predicted. These scenarios should also be considered as Category 4 since it is unlikely that the controller could tell the reason for the alert, and thus would be distracted by it, if it is not clear with the full aircraft path(s) available for detailed examination.

4.3.7 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 STCA meet their 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 Introduction

STCA will provide an amount of time in which the situation may be dealt with ("warning time"). The warning time is measured as the time between the STCA alert and the Point of Risk (PoR). Flexibility in the calculation of warning times, depending on the rationale behind a STCA implementation, is provided by appropriately defining how the PoR is determined.

For non-predictive functions, the warning time is entirely produced by the size of the protective "buffer zone". The size of the buffer zone must therefore be optimised for the nature of the traffic in that region.

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 and the "adequate" warning time may vary between different types of airspace. 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 STCA 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.

It may be possible for an aircraft to perform an avoidance manoeuvre in the vertical plane in a shorter time than it would take to perform a manoeuvre in the lateral plane. For some implementations, it may therefore be desirable to distinguish between those scenarios which can be resolved vertically and those which cannot. For these implementations it will be necessary to specify separate adequate warning times for vertical and lateral avoidance manoeuvres

4.5.3 Maximum warning time

The maximum warning time is the time between the earliest possible point at which an alert could be given and the PoR. The earliest possible point of alert is determined by finding the point in the surveillance track data prior to the conflict where a manoeuvre occurred that could not have been foreseen by STCA. The track states are inspected, working back from the actual alert until one of the following is found:

- A vertical state change
- A horizontal state change
- The start of the track

Vertical state changes, particularly where aircraft change from level flight to climb or descend towards the potential hazard, are often responsible for limitations in the maximum amount of warning time available. In general, substantial changes in vertical rate cannot be anticipated by tolerances in vertical prediction. A vertical state change occurs when an aircraft:

- Changes from level flight to climb or descent
- Changes from climb or descent to level flight
- Changes vertical direction (climb to descent or vice versa)

Lateral state changes are not as easily defined (or determined) as vertical state changes. In many cases lateral tracks exhibit slow turns or meanders for which the starting points are very indistinct. However, an appropriate definition of the point of lateral manoeuvre has been defined for STCA purposes. The track states prior to the conflict are inspected until a point is reached where the predicted lateral miss distance is greater than a parameter distance.

STCA implementations which include an element of uncertainty in the prediction mechanism may be better able to cope with state changes. However, there will still be manoeuvres which take an aircraft's new path outside the scope of that previously predicted.

4.5.4 Objective warning time

It is not considered appropriate to provide STCA alerts in excess of the adequate warning time before the PoR actually occurs. This is to avoid unnecessary controller distraction by an increased number of unwanted alerts. However, in some situations, the maximum warning time is smaller than the adequate warning time. In these situations it is not possible to achieve the adequate warning time and effort should therefore be concentrated on achieving the maximum warning time.

The aim is therefore to provide an alert at the lesser of the adequate warning time and the maximum warning time. This is the objective warning time, and is the optimum time for the alert.

Figure 23 shows a situation where the maximum warning time is less than the defined adequate warning time. The maximum warning time is therefore taken as the objective warning time for this particular scenario.

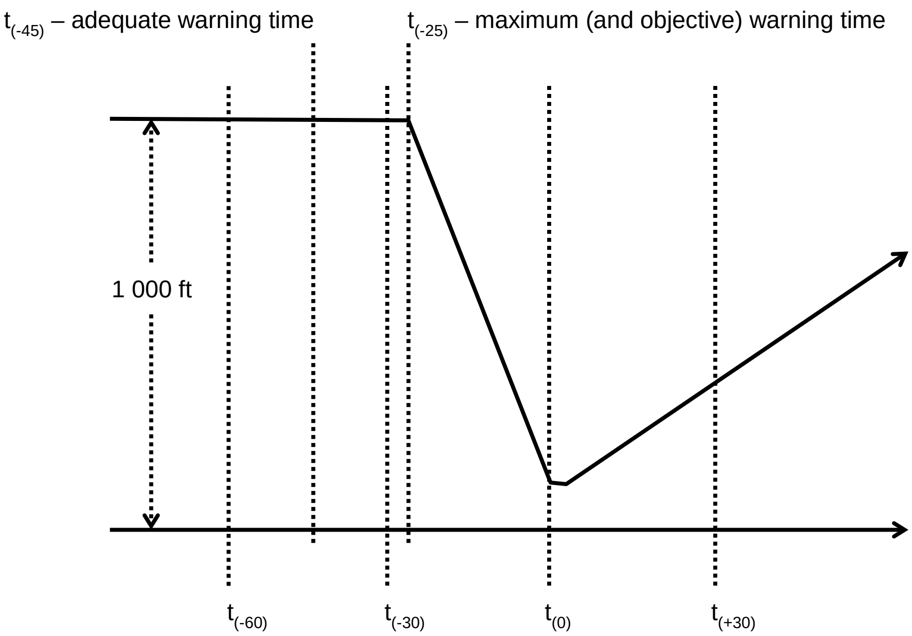


Figure 23: Example of maximum warning time less than adequate

4.5.5 Achieved warning time

The achieved warning time is the actual time between the STCA alert and the conflict.

Where a predicted PoR is used to assess the performance of a multi-filter STCA, the method of calculating the PoR (and thus the achieved warning time) must be appropriate to the filter which caused the alert. For example, the PoR appropriate to the Linear Prediction filter of an STCA function may well be very different from that appropriate to the Current Proximity filter.

4.6 Point of risk

The concept of the PoR is used in this document to provide a single term to represent the point from which warning times are retrospectively measured. The nature of the PoR will vary between implementations, depending on the underlying rationale behind the specific implementation. The PoR can be considered as a point on either the actual or predicted aircraft path(s) and may deal with distances in time, space or a combination of the two, as appropriate to the function and implementation.

The PoR may or may not be the same as the point which triggers the STCA alert. This again depends on the approach taken by the function designers and analysts.

For predictive STCA functions, the PoR could be defined as the Closest Point of Approach (CPA) or the breach of some specified separation criteria (such as the ATC separation standards). It should be noted that longer warning times are required when CPA is used as the PoR as opposed to breach of separation criteria in order to provide the same level of safety. Figure 24 illustrates some types of PoR which could be used for STCA.

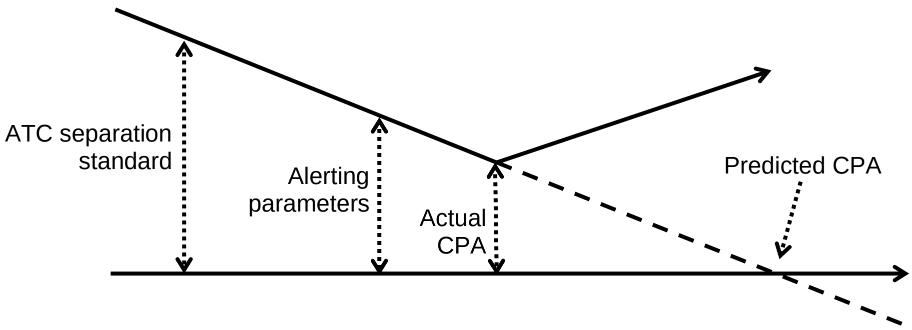


Figure 24: Example Points of Risk for STCA

It may be appropriate to use smoothed track data to determine the PoR, rather than the system tracks, from which alerts are generated. This is because the true PoR lies on the actual path(s) flown by the aircraft and this is (these are) best represented by smoothed data.

4.7 Closest point of approach

4.7.1 Introduction

In its simplest definition, the CPA is the point where the distance between the aircraft of interest and other aircraft is at a minimum.

Determining which point constitutes the CPA requires some consideration. In order to make the distance meaningful in an ATC sense, the physical units of lateral and vertical distance have to be converted into a single value, determined from the ATC separation standards in the region as follows:

LU = lateral distance / lateral separation unit

ZU = vertical distance / vertical separation unit

$DU = \sqrt{(LU^2 + ZU^2)}$

The CPA is the point at which DU reaches a minimum. The separation units would typically be the appropriate ATC separation standards for the airspace concerned, for example 5 NM and 1 000 ft. This approach gives equal weight to breaches of horizontal and vertical separation standards.

4.7.2 Predicted CPAs

The actual CPA is not always the most useful measure of separation loss on which to base STCA performance figures. For example, if an aircraft takes avoiding action as the result of an alert this will affect the minimum achieved separation and the time of the CPA and consequently the perceived warning time. In some circumstances, such as calculating warning time, it may be more useful to extrapolate the aircraft track(s) from before the avoiding action to determine the CPA which would have been predicted by STCA. Figure 25 illustrates the variation in warning time which may be seen for one STCA scenario.

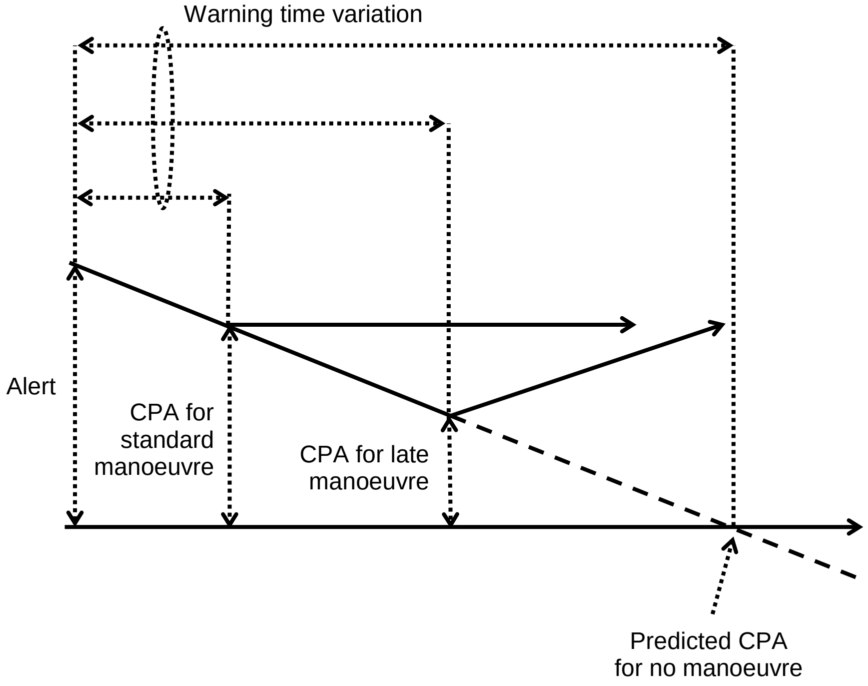


Figure 25: Examples of warning time variation

The predicted CPA must be calculated in a way which is compatible with the particular operation of STCA which generated the alert. For multiple filter STCA, a number of predicted CPAs may need to be determined - one for each filter. Suggestions as to these are given below:

- The CPA for a linear prediction filter is determined by linearly extrapolating the aircraft track state(s) at the time of the alert
- The CPA for a filter which detects turning aircraft should be extrapolated from the aircraft track state(s) at the time of the alert, using the same level of turn prediction as the STCA filter

- The CPA for a current proximity filter may be better determined by using the actual CPA rather than a predicted one since the closing speed(s) may be very small (or even negative), however, the determination of the CPA should be restricted to within a reasonable time of the alert

If the scenario would generate an alert by more than one filter, the CPA for the first filter to generate an alert should be used. If two or more filters generate an alert simultaneously, they should be prioritised in the order:

- Current proximity
- Linear prediction
- Turn prediction

4.8 Region types

STCA needs to be able to behave differently in different regions of airspace. For example, separations are larger in en-route airspace than near airports. Rather than assign parameter values to individual regions, groups of regions defining similar airspace may be collectively assigned a region type and then parameter values assigned to that type.

Determining the appropriate region types will normally require consultation with controllers.

4.9 Analysis tools

4.9.1 Introduction

STCA 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.

4.9.2 Off-line models

It is vital that STCA performance can be optimised and monitored without affecting the operational ATC system. The most efficient way of doing this is probably via a series of off-line computer models which accurately replicate the algorithms of the (proposed) STCA. It is preferable that the models are not contained within the main ATC simulation/test facility since they will be used intensively during optimisation phases and are therefore best used under the exclusive control of the STCA analysts. The models 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 models should also produce the Performance Indicator information.

If the operational STCA can be run in an off-line environment and generate adequate analysis information, it is not necessary to use off-line models. However, using the operational STCA 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 STCA it is used to test, even if the actual programming source code is different. Different versions of a STCA will therefore require different versions of the model otherwise the results of the optimisation may be invalid.

The models 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.

4.9.3 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. One convenient way of displaying scenarios is via printed diagrams showing plan and elevation views of the scenario, although alternative methods may prove to be equally satisfactory. 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 region boundaries have been located correctly and subsequently for identifying any part of the airspace with an unexpectedly high alert rate. The facility to display actual tracks on a map may prove useful when defining region boundaries in the first place.

4.9.4 Categoriser

STCA 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 the “categoriser”, is totally independent from the simulation function of the STCA model. The categoriser classifies scenarios according to categories and will work retrospectively over the entire scenario.

The whole track(s) of the aircraft during the scenario is (are) available for examination by the categoriser. The seriousness of the scenario is determined by considering the predicted and actual CPA at each cycle. The time to, and predicted separation at, the predicted CPA can be used to establish the seriousness of the scenario for each cycle. The seriousness of the scenario may then be determined from the seriousness of the individual cycles. It may also be necessary to consider the seriousness of the scenario from an ATC perspective when assigning a category as the scenario’s geometry alone will not necessarily give a satisfactory indication of the true nature of the scenario.

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 STCA 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.

The categoriser will, where appropriate, need regions to determine the relevant parameters. These regions may be similar to those used in the STCA under consideration but need not necessarily be exactly the same.

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 STCA can highlight problems in other parts of the data processing chain. As optimal STCA 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 STCA 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.

4.9.5 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 calculated as the time between the alert and the PoR. This should be done using different algorithms from those contained in the actual STCA since the “actual” elapsed time is available for measurement, rather than a predicted version.

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.

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

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

Figure 26 shows the main tasks involved in the first optimisation of STCA. Some of the initial tasks may not need to be undertaken when the system is re-optimised at a later date. Once Parameter Sensitivity Analysis has been performed for STCA, it should not need to be redone for subsequent implementations of that STCA at other ATS units.

Figure 27 and Figure 28 each provide a more detailed indication of the steps involved in a particular task shown in Figure 26.

Figure 27 shows the steps taken in the actual iterative process of determining the optimal parameters.

Figure 28 shows the steps involved in the operational trial of STCA 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.

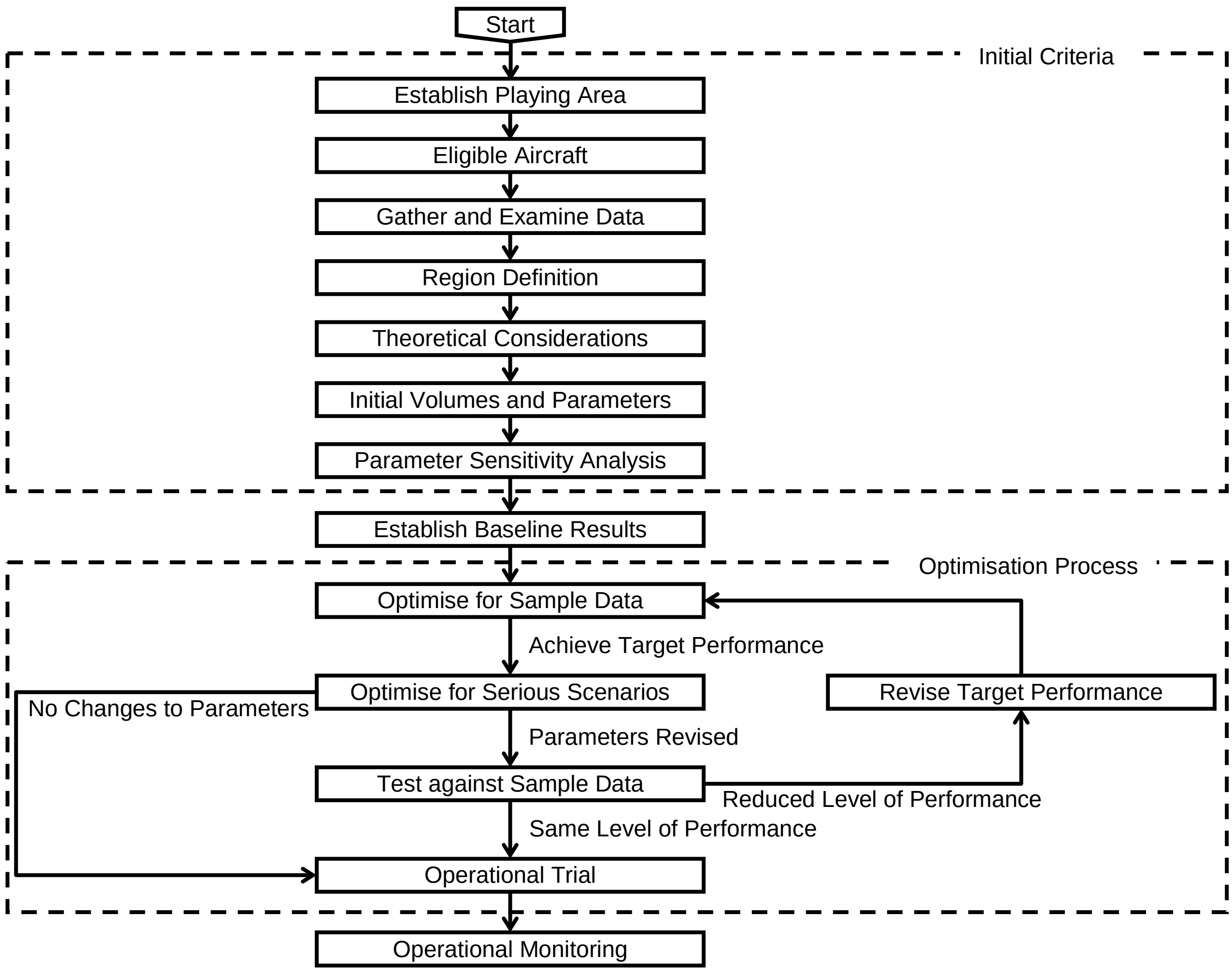


Figure 26: System adaptation tasks

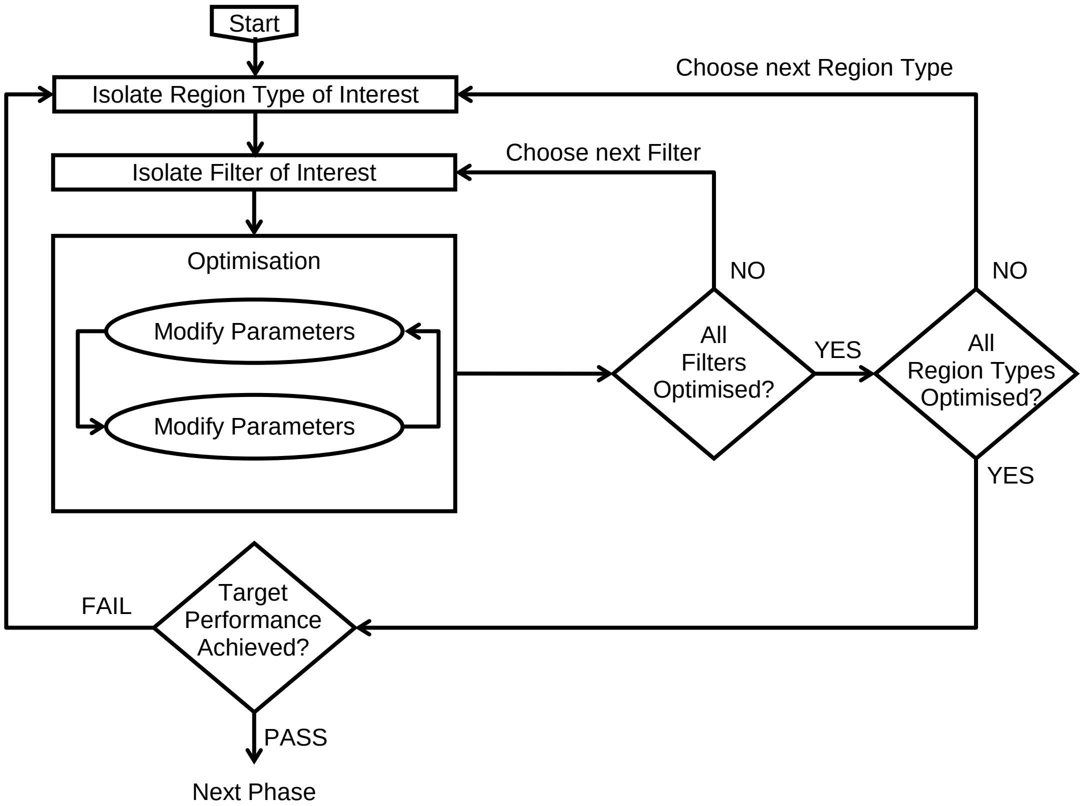


Figure 27: Iterative optimisation

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

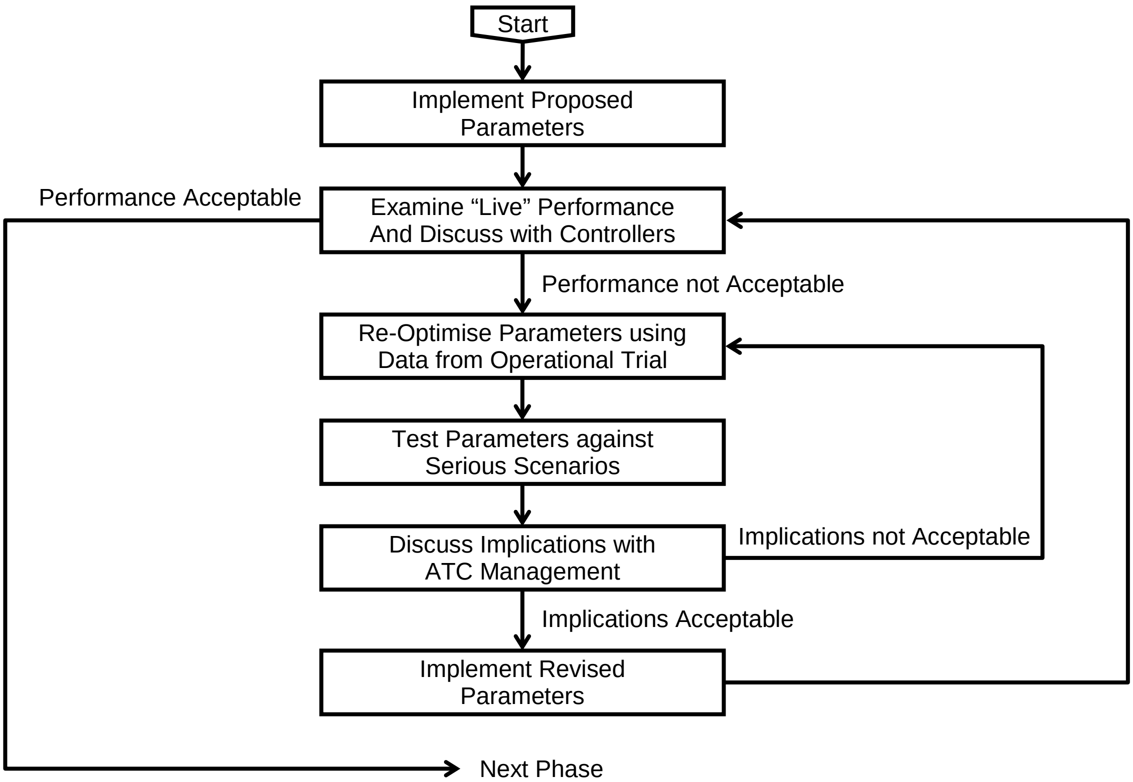


Figure 28: Operational trial

5.2 Initial criteria

5.2.1 “Playing Area” definition

It may be impracticable, from both the operational and development points of view, for STCA to be treated as covering all the airspace which is potentially available from Surveillance Data Processing. It is therefore necessary to define a “playing area” for each system. The playing area represents the extreme boundary of the airspace which is of interest to both the operational STCA and the development and analysis team.

The limits of the playing area will normally be determined by the area of responsibility of the ATS unit(s) for which STCA is being optimised. The playing area should exceed the controlled airspace by an appropriate margin to ensure that tracks are recorded for aircraft in the handover area. A simple geometric shape such as a rectangle is usually sufficient since the primary purpose of the playing area is to discard aircraft which cannot be of interest to the controllers or analysts.

5.2.2 Eligible aircraft

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

It is therefore vital that off-line STCA simulations have correct information available as to the (in)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 STCA 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 STCA parameters to take account of SSR code changes.

STCA which uses a link to Flight Data Processing to indicate eligibility will not normally 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.

5.2.3 Data

5.2.3.1 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 region types 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 during slack periods and in different weather conditions since these may affect the traffic patterns.

5.2.3.2 “Serious” scenarios

The purpose of STCA is to alert controllers to situations which have gone seriously wrong. Such situations are not an everyday occurrence but it is important that STCA 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 the location of a holding area has moved incidents recorded at the previous location may need to be discarded.

5.2.3.3 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.

5.2.4 Region definition

An initial set of regions (and region types if applicable) has to be determined before the optimisation process may start. Determining the region set will normally involve discussions with controllers and examination of the traffic patterns evident from recordings. Published airspace boundaries will normally provide a good starting point for determining regions.

Within the playing area there may be volumes of airspace not under the control of the ATS unit. These may be defined as uncontrolled or excluded altogether.

Within the controlled airspace regions there may be areas which have specific types of traffic pattern, such as the stacks in a TMA. It may be necessary to define these areas as separate regions. The definition of such regions will require close consultation with the appropriate ATC personnel.

As regions may overlap precedence must be determined for each individual region. Additionally, regions may be set to “active” or “inactive” depending on factors such as weather conditions or military use of airspace.

If different region types are to be used for STCA, there will probably be scenarios in which the two aircraft are in regions of different type. To deal with this, some means, such as a decision matrix, must be devised so that the appropriate region type (and hence parameter set) can be determined for each scenario. The decision matrix may choose one region type over the other or allocate the scenario to a third type reserved for such situations.

5.2.5 Theoretical considerations

5.2.5.1 Summary

Theoretical issues which need to be considered when determining STCA parameters include:

- Typical aircraft performance capabilities
- Typical local traffic manoeuvres
- Desired warning times
- Desired look ahead times
- Surveillance tracking performance
- Separation standards
- ATC operational procedures
- Provision for intruders

These issues will provide practical limits to the potential ranges for the values of a number of STCA parameters.

5.2.5.2 Typical aircraft performance capabilities

Typical aircraft performance capabilities have to be considered when determining appropriate ranges for many parameters. For example, civil controlled aircraft typically do not exceed ground speeds of about 550 kt nor climb at rates in excess of 5 000 ft/min. However, military aircraft can, and do, exceed these limits and allowance may have to be made for them.

Typical aircraft performance limits allow the maximum typical closing speeds to be determined. When combined with the desired warning and look ahead times, these can be used to determine the theoretical vertical and lateral separations beyond which STCA needs not consider aircraft with respect to a particular other aircraft. In multi-stage systems this sets constraints for the upper limits of many coarse filter parameters.

Aircraft turn rates may also need to be considered. Most civil aircraft can normally achieve a standard rate of turn of 3º per second but it cannot be assumed that they can necessarily achieve higher rates. 3º per second therefore could be considered to constitute an upper constraint for parameters associated with turning aircraft, although the characteristics of aircraft which use the airspace under consideration should be examined.

5.2.5.3 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 in TMA airspace tend to fly at lower ground speeds than those in en route airspace. Climb and turn rates may also be restricted or even determined by the nature of the airspace. Certain areas have concentrations of particular types of traffic (e.g. helicopters) which result in well-defined manoeuvring activity.

These local restrictions are more difficult to determine than the absolute aircraft performance limitations. Typical ground speeds and climb rates may be obtained from surveillance data but ATC personnel should be consulted wherever possible to ensure that all local aspects have been considered.

5.2.5.4 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 parameters related to reaction times. Local variations in aircraft types and operations may result in corresponding variations to the minimum desired warning time.

5.2.5.5 Desired look ahead times

The minimum look ahead time is that which provides for the minimum warning time plus the STCA processing time. The desired look ahead time must therefore be at least the desired warning time plus the processing time. However, the alert rate is likely to be sensitive to the look ahead time and this must also be considered when setting such parameters to avoid producing an excessive number of nuisance alerts.

5.2.5.6 Surveillance tracking performance

Surveillance tracking performance should be considered when determining the ranges for predicted separation parameters. Two theoretical approaches can be adopted. The first approach is to set the parameters to large enough values to ensure that all predicted conflicts will be detected, even when poor tracking means that there are large errors in the aircraft heading values. The second approach is to set the parameters to smaller values to reduce the number of spurious alerts caused by poor tracking or small fluctuations in aircraft trajectories.

5.2.5.7 Separation standards

The appropriate separation standards should be treated as upper limits for a number of STCA parameter values. Values in excess of the separation standards will result in nuisance alerts being generated by aircraft that are neither infringing nor predicted to infringe separation standards.

5.2.5.8 Provision for Intruders

In this context, intruders are taken to be those aircraft not under the control of the ATS unit in question which are flying in that unit's airspace. Intruders will normally be identified by SSR code or a lack of Flight Data Processing information.

A controller usually has less information about the intended course of an intruder than that of a controlled aircraft. Larger warning times and separation criteria may therefore be required to enable STCA to deal with scenarios involving an intruder in a useful manner. However, the treatment of intruders is a matter which is very much dependent on the practice and requirements of individual ATS units and is not a subject which can be dealt with in detail in a document of this nature.

5.2.6 Initial parameter set

The initial optimisation process will not have an existing parameter set to use as a base-line. The initial parameter set is therefore determined from the theoretical criteria above, plus any other appropriate information. Future modifications to existing systems should normally use the operational parameter set as the base-line.

5.2.7 Parameter sensitivity analysis

5.2.7.1 Introduction

Before attempting to optimise the parameters it is important to know which ones have the most effect on the alert rate and how related parameters depend on each other. This allows effort to be directed appropriately during optimisation and helps to ensure that inconsistent or redundant parameter values are not used.

Parameter sensitivity analysis usually only needs to be performed once for a system since the sensitivity will not normally change. It may therefore not be necessary for an analysis to be performed before the optimisation of systems which have already been implemented at other ATS units.

5.2.7.2 Method

The first step in parameter sensitivity analysis is to pass appropriate surveillance data through the STCA computer model, using the agreed base-line parameter set. The alert rates produced by this parameter set provide a reference level against which all future results may be compared.

Parameters may then be varied in turn to determine their effect on the alert rate. Parameters should normally only be varied within ranges which are consistent with the theoretical considerations discussed above.

The size of the increments over which each parameter is altered will initially be rather arbitrary, although the following factors may be taken into account:

- The time available for the task; it is better to try large increments first in order to discover where the greatest areas of alert change are. These areas of change may then be “filled in” by using smaller increments.
- Small increments are only needed around the area in which the optimum is believed to exist.

As well as changing the values of each parameter in turn, it is also necessary to examine the effect of varying combinations of related parameters. Appropriate groups of parameters should be determined from the specification for each individual system.

When the model has been used with all the proposed parameter sets the resulting alert rates need to be examined and compared. Graphs of alert rates for varying parameters may prove to be as, or more, useful than tables of results. It may be helpful if the graphs for groups of related parameters are superimposed.

5.2.7.3 Aspects of graphs for consideration

5.2.7.3.1 Graph shape

The alert rate may increase or decrease as the parameter value is increased. Alternatively the rate may be unaffected by changes in a particular parameter. This could indicate that the parameter under consideration is redundant given the other parameter values chosen or that the data sample does not test the relevant algorithm properly.

5.2.7.3.2 Gradient

The gradient of the graph indicates the sensitivity of the alert rate to changes of the parameter.

Measuring the gradient is easy for graphs with a constant slope. Where the slope is constantly changing, the gradient should be measured at significant points only, such as when the slope is at its maximum value or after a gradient change. Reasons for the changes in gradient should be sought. This information may, by itself, be sufficient to derive potentially optimal parameter values; however, any such values should, of course, be thoroughly checked during the optimisation process.

Parameter variations which produce a graph that changes its slope (especially those which change direction) must be investigated thoroughly. A change of slope could indicate that the parameter has a dual action or that it is used in different parts of STCA. A change of slope could also indicate that the alert output includes possible errors - for example, a single continuous alert might be divided into two short alerts. Investigating such slope changes may require considerable effort and a detailed inspection of system debug information.

5.2.7.3.3 Superimposed graphs for different parameters

In some circumstances it may be useful to superimpose graphs to check for parameter interdependence. If the graphs of alert rate against a parameter value have different shapes for different values of a second parameter this could indicate that the parameters are interdependent. This would normally mean that the total alert rate change arising from the combined parameter change is different from the sum of the alert rate changes arising from the individual parameter changes.

It may be the case that one parameter will not affect the alert rate until a certain threshold value of the other related parameter has been reached.

Superimposed graphs may also show variations in the sensitivity of the alert rate to a parameter. A large difference in alert rate between similarly shaped graphs indicates that the alert rate is particularly sensitive to the parameter being varied to produce the different graphs.

5.2.7.3.4 Regional variation in parameter action

Where parameters have different values in different region types it may be useful to compare the graphs from the different region types.

5.2.7.3.5 Comparison of graphs

The parameter sensitivity data obtained from the graphs provides a means of prioritising the parameters for the main optimisation. However, since different parameters have different units it is not always possible to compare like with like when comparing graphs. This is particularly true when comparing vertical parameters with lateral ones. It is therefore more useful to consider parameter sensitivities in terms of the proportion of the change in alert rate that is produced by varying each parameter over the total viable range of values for that parameter.

The shape of the graphs is likely to be a useful guide to the relative importance of different parameters. Parameters which produce exponential graphs tend to be of more importance (for optimisation purposes) than those which produce linear graphs.

5.2.7.4 Parameter interdependencies

Parameter sensitivity analysis is also intended to indicate those parameters which are interdependent.

A simple example of parameter interdependence is that which exists between a fine filter parameter and the corresponding (and preceding) coarse filter parameter. The value of the fine filter parameter must be more restrictive than the value of the coarse filter parameter; otherwise the fine filter parameter is redundant.

Parameter interdependencies can be used to supplement the external constraints in determining the viable ranges over which individual parameters should be optimised. Examination of the parameter interdependencies may also indicate inconsistencies in the STCA algorithms themselves.

5.2.7.5 Results

When the parameter sensitivity analysis has been completed the following information should be available:

- A list of the most important parameters in terms of their effect on the alert rate (this gives a priority order for examining the parameters during optimisation)
- Hypotheses on optimal values for certain parameters (these may result in changes to the initial parameter set prior to the optimisation)
- Ranges for all the parameter values which ensure that external constraints and parameter interdependencies have been taken into account; in practice this means determining upper and lower bounds for each parameter, either in absolute terms or in terms of other parameter values; this minimises the risk that inconsistent or redundant parameter values will be set
- An estimate of regional variations in parameter values (if appropriate)

5.3 Baseline results

Once theoretical values have been determined for each parameter, the parameter set should be run against the sample test data. This produces a set of results to be used as the baseline for the parameter optimisation process.

When optimisations are being performed on STCA which are 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 parameter optimisation process is undertaken at least twice - first with the sample data and then with the specially selected serious scenarios.

Where region types have been defined, optimisation should initially be performed for each region individually. However, region types cannot be considered in total isolation from each other since it may be that individual regions have not been optimally defined. This would lead to inappropriate parameter sets being used in certain areas and thus an incorrect set of “optimised” parameters. The correct definition of the individual regions must therefore also be considered along with the parameters.

Within each region type, effort should be concentrated on one filter at a time when multiple-filter functions are being considered. However, it is probably inadvisable to disable the other filters since then the parameters could be optimised for inappropriate scenarios.

Once a region type and filter have been selected, the iterative process of modifying parameters (and possibly region boundaries), running the new parameter set against the data and determining the results for individual filter/region type/parameter set combinations begins.

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 function. The efficient and effective optimisation of STCA is dependent on the analysis team's skill and knowledge of the system under examination.

The way in which the results from individual filter/region type/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 parameter sensitivity analysis results combined with the expertise of the analysis team are crucial in determining which combinations should be examined and which may be ignored.

The iterative optimisation process should be performed for all filters and region types. Any changes to region boundaries should be tested for impact on the other region type(s) which have gained or lost volumes of airspace.

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

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 STCA. 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, airspace design, SSR allocations and ATC practice all change with time. These factors have a bearing on the “optimum” parameter set for STCA. Parameter optimisation 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 STCA 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 STCA systems.

6.2 Routine data recording

In most ATC systems, data such as surveillance plots, system tracks, alerts 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 STCA data that is recorded routinely generally includes the alert messages and may also include STCA status (or alive, or heartbeat) messages. Other information related to STCA may also be routinely recorded, such a flight plan data, region activations/deactivations 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 STCA data must contain sufficient information and must be precise enough to allow the correct functioning of STCA to be verified.

If a test STCA system is used for parameter optimisation then at the very least, the STCA 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 STCA functioning, whilst desirable items of data may provide further valuable details.

Much of the STCA recorded data is related to specific track pairs. Each track pair contains the 3D state vector (X, Y, Z, VX, VY, VZ) of a pair of system tracks. The pairs are recognised by the coarse filter and processed by the subsequent fine filters and may give rise to an alert. Therefore, the recorded data must include the track data that constitutes a pair.

Recorded data may be grouped as follows:

- Environment data (desirable, but may be obtained from elsewhere)
- All system tracks available to STCA (desirable, but bulky)
- Track pairs that have passed the coarse filter (required)

- Values calculated for the pair before or during the fine filters (required)
- Flags and results of fine filters (required)
- Alert messages (required)
- Additional information such as region activation or QNH (required)

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 pairs (using a pair reference number), so that the inputs to STCA and the STCA functioning and output can be analysed on a pair by pair 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 is unlikely to be required once the STCA coarse filter has been verified.

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 STCA parameters, STCA regions, as well as any other items related to STCA processing such as QNH regions or region activation status, if in use.

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 STCA. This would allow the correct functioning of the coarse filter to be tested, and could allow track pairs that have not passed the coarse filter to be examined.

6.5 Track pairs

All the track pairs that have passed the coarse filter are required in the recorded data file. The track pair data must include all the track information relevant to STCA in sufficient precision to allow a full analysis of the pair 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
- Turn direction and rate, if used by STCA
- Track age and quality information used by STCA
- Data such as the type of flight, call sign, RVSM status, CFL, SFL (if used)

6.6 Values calculated before or during the fine filters

The values calculated before or during the fine filters should be sufficient to allow the STCA processing to be properly examined. The information should include:

- The pair reference (indicating the track numbers involved in the pair)
- The region number for each track
- The parameter group for the pair
- The current lateral separation of the tracks, L
- The current vertical separation of the tracks, dZ
- The ATC vertical separation rule to be applied (1 000 ft or 2 000 ft)
- The predicted lateral miss distance (by linear prediction, if computed)
- The start and end times of the lateral violation, TLS and TLE (if computed)
- The start and end times of the vertical violation, TVS and TVE (if computed)
- The overall time of violation, TOV
- The Conflict Hit Counter value

Other information should be included, if it is relevant to the particular STCA system. e.g.:

- The relative velocity of the tracks
- The converging or diverging speed of the tracks
- The relative vertical rate of the tracks
- The minimum separation achieved by the predicted turn as calculated by the turning prediction filter
- The time of violation, TPTOV, as calculated by the turning prediction filter

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/s 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 STCA system. They allow the user to follow the logic of the STCA processing and to see the reason why there was or was not a conflict for a particular pair.

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

Flags before the fine filters:

- Track pair is in an exclusion region
- Track pair is eligible for STCA processing (or reasons for non-eligibility)
- Coarse filter passed
- Pair is laterally fast diverging
- Pair is vertically fast diverging

Linear Prediction Filter Flags:

- Linear prediction filter called

- Lateral miss distance within **LinearPredictionLateralSeparation[n]**
- Lateral violation within **LinearPredictionTime[n]**
- A vertical violation is predicted
- Vertical violation is within **LinearPredictionTime[n]**
- Lateral and vertical violation intervals overlap
- Linear prediction filter conflict hit detected

Current Proximity Filter Flags:

- Current proximity filter called
- Tracks within **CurrentProximityLateralSeparation[n]**
- Tracks within **CurrentProximityVerticalSeparation[n]**
- Current proximity filter conflict hit detected on this cycle

Turning Prediction Filter Flags:

- Turning prediction filter called
- A vertical violation is predicted
- At least one track is turning
- Predicted lateral separation < **TurningPredictionLateralSeparation[n]**
- Lateral violation is within the vertical violation time
- Turning prediction filter result

Linear Prediction Filter Alert Confirmation Flags:

- Conflict is imminent - time of violation, TOV, is within **LinearPredictionImminentTime[n]**
- Count of conflict hits is sufficient (>= **LinearPredictionConflictCount[n]**)
- Time of violation, TOV, is within **LinearPredictionWarningTime[n]**
- There is time for a standard single level off manoeuvre
- There is time for a standard double level off manoeuvre
- The is time for a standard turn
- Linear prediction filter alert confirmed

Current Proximity Filter Alert Confirmation Flags:

- Count of conflict hits is sufficient (>= **CurrentProximityConflictCount[n]**)
- Safe crossing situation
- Current proximity filter alert confirmed

Turning Prediction Filter Alert Confirmation Flags:

- Conflict is imminent - time of violation, TPTOV, is within **TurningPredictionImminentTime[n]**
- Count of conflict hits is sufficient (>= **TurningPredictionConflictCount[n]**)
- Time of violation, TPTOV, is within **TurningPredictionWarningTime[n]**
- Turning prediction filter alert confirmed

6.8 Alert messages

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

- The pair reference number
- Both system track numbers
- Any other information relevant to the alert

6.9 Additional information

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

- Changes to the QNH and/or the transition level
- Changes in the status of an STCA region

7. Test scenarios for STCA

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 STCA system
- To demonstrate the variety of types of situation for which STCA is expected to perform

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

The test scenarios are useful to demonstrate the variety of mid-air situations that can occur between aircraft. It is not desirable to improve the alerting performance for one type of situation at the expense of the performance in other situations. Therefore, as part of the parameter optimisation process, the different types of situation must be properly 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. The times at which significant events occur may also be shown on the pictures.

All (x, y) coordinates are relative coordinates. The coordinates and flight levels should be relocated to appropriate values in the environment for which the STCA system under test is optimised.

7.3 Derivation of the performance targets

The performance targets were derived by using the appropriate equations of assumed motion (straight-line equations, where the aircraft were on straight courses, and circular equations where the aircraft were turning). The expected time of the alert was then calculated using the parameter values at the narrowest end of the recommended range, and taking full account of the delay that might be added by the alert confirmation stage, including conflict counts and other delay mechanisms.

Where the aircraft are in vertical transition, the flight level at the target time has been given. This may be a convenient way of checking the timing of the alert on an ATC display.

7.4 List of test scenarios

The test scenarios are:

- Simultaneous lateral and vertical convergence
- Aircraft converging laterally at the same flight level

- Departure from flight level situation – 1 000 ft
- Departure from flight level situation – 2 000 ft
- Aircraft laterally slow closing on the same flight level
- An aircraft levels off at an occupied level (optional input of CFL and/or SFL)
- Aircraft climbing and converging vertically
- Aircraft proceeds out of exclusion region into imminent conflict
- One aircraft turning towards another into conflict
- Two aircraft turning towards each other into conflict
- Aircraft cross laterally then cross vertically

7.5 Simultaneous lateral and vertical convergence

7.5.1 Objective

The objective of this scenario is to test STCA performance in the very simple case of simultaneous horizontal and vertical convergence.

7.5.2 Aircraft geometry

The scenario is set in en route airspace where straight courses are more common than in the TMA. Both aircraft are fully eligible for STCA processing. The simulated aircraft are arranged to collide at t = 120 s after the start of the scenario. The scenario is depicted in Figure 29.

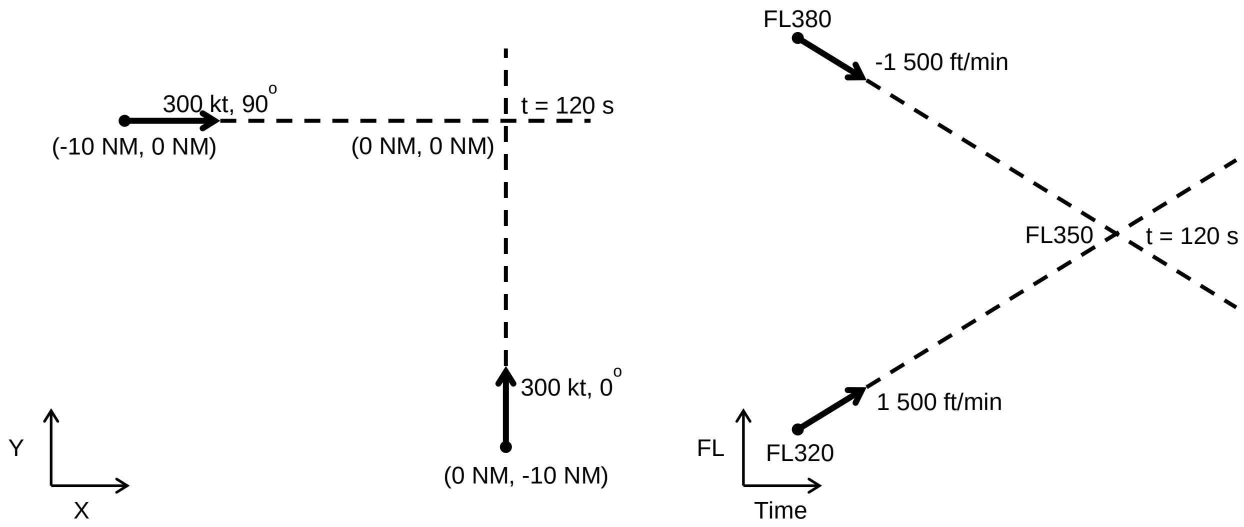


Figure 29: Simultaneous lateral and vertical convergence test scenario

7.5.3 Target result

The STCA alert should be displayed at least at t = 80 s before the collision. That is, before aircraft are at FL330 and FL370 respectively. Ideally, the warning time achieved before collision would be t = 90 s or more.

7.5.4 Significant parameters

The exact timing of any STCA alert will depend on the following parameters:

- **LinearPredictionHorizontalSeparation[n]**
- **LinearPredictionVerticalSeparation[n]**
- **LinearPredictionWarningTime[n]**
- **LinearPredictionConflictCount[n]**
- Also, “Time for standard manoeuvre” parameters, if used

7.6 Aircraft converging laterally at the same flight level

7.6.1 Objective

The objective of this scenario is to test STCA performance when two aircraft at the same flight level are converging horizontal.

7.6.2 Aircraft geometry

The scenario is set in en route airspace where straight courses and level flight are more common than in the TMA. Both aircraft are fully eligible for STCA processing. The simulated aircraft are arranged to collide at t = 120 s after the start of the scenario. The scenario is depicted in Figure 30.

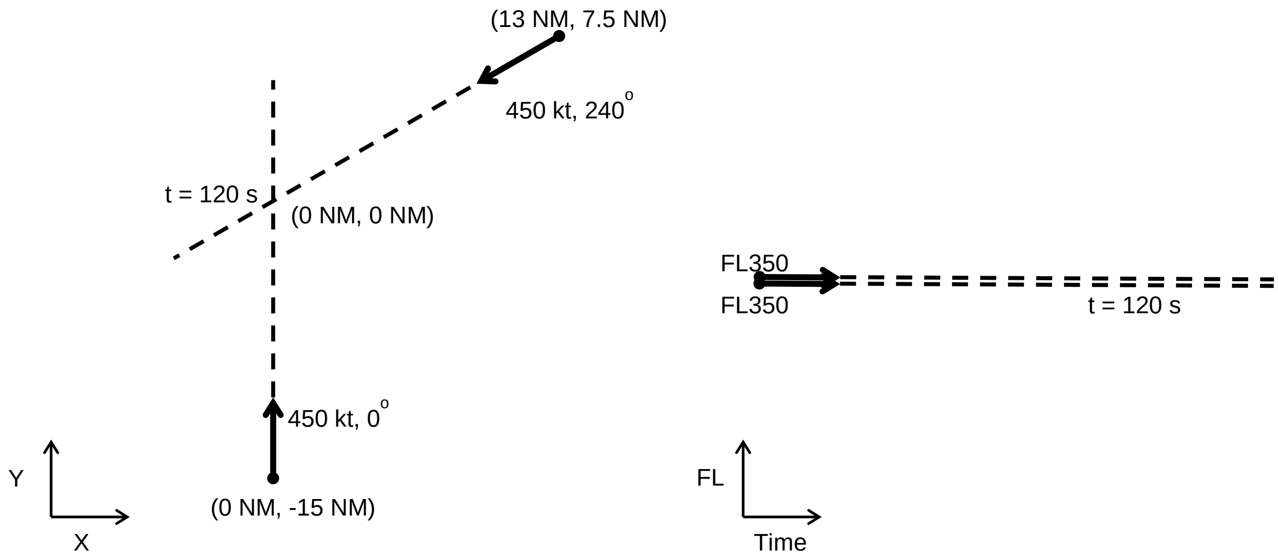


Figure 30: Aircraft converging laterally at the same flight level test scenario

7.6.3 Target result

The STCA alert should be displayed at least at t = 50 s before the collision. That is, before the horizontal separation of the aircraft has reduced to 10.8 NM. However, ideally, in situations where aircraft are at the same flight level, a warning time (before collision) of significantly more than t = 60 s is desirable

7.6.4 Significant parameters

The exact timing of any STCA alert will depend on the following parameters:

- **LinearPredictionHorizontalSeparation[n]**
- **LinearPredictionVerticalSeparation[n]**
- **LinearPredictionWarningTime[n]**
- **LinearPredictionConflictCount[n]**
- Also, “Time for standard turn” parameters, if used

7.7 Departure from flight level situation – 1 000 ft

7.7.1 Objective

The objective of this scenario is to assess the performance of STCA when one aircraft rapidly departs from one flight level towards another occupied level 1 000 ft away and into serious conflict.

The "departure from flight level" situation is one for which only a very short warning time is available. Therefore it is essential that STCA alerts as soon as the track data indicates a descent towards the next flight level.

7.7.2 Aircraft geometry

The scenario may be set in any location (en route, TMA, holding area) where 1 000 ft ATC vertical separation applies. The aircraft remain in close horizontal proximity (within **LinearPredictionHorizontalSeparation[n]** and **CurrentProximityHorizontalSeparation[n]**). They are initially separated by 1 000 ft vertically. At some time, the higher aircraft descends at 1 500 ft/min towards the lower aircraft. The scenario is depicted in Figure 31.

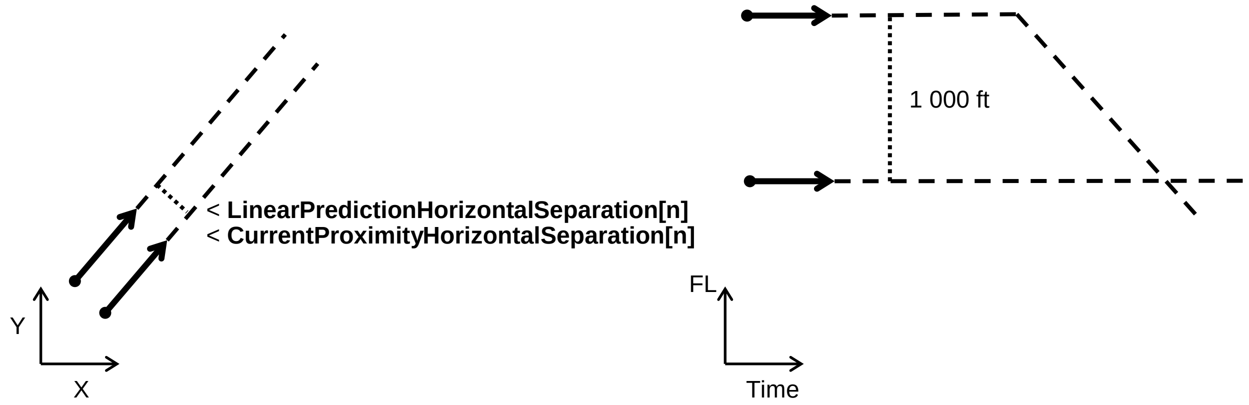


Figure 31: Departure from flight level situation – 1 000 ft test scenario

7.7.3 Target result

Because of the very limited available warning time, STCA must alert as soon as the tracker indicates a vertical manoeuvre towards the next flight level.

Failure to achieve a rapid STCA alert, suggests that the parameters are not properly tuned to take this type of situation into account. A delayed alert may also indicate that the vertical tracker is not optimised to follow such a manoeuvre.

7.7.4 Significant parameters

The following parameters are significant to STCA performance in this scenario:

- **LinearPredictionVerticalSeparation[n,1000]**
- **LinearPredictionImminentTime[n]**
- **LinearPredictionConflictCount[n]**

7.8 Departure from flight level situation – 2 000 ft

7.8.1 Objective

The objective of this scenario is to assess the performance of STCA when one aircraft rapidly departs from one flight level towards another occupied level 2 000 ft away and into serious conflict.

The "departure from flight level" situation is one for which only a very short warning time is available. Therefore it is essential that STCA alerts as soon as the track data indicates a descent towards the next flight level.

7.8.2 Aircraft geometry

The scenario is best set in en route airspace where 2 000 ft ATC vertical separation applies. The aircraft remain in close horizontal proximity (within **LinearPredictionHorizontalSeparation[n]** and **CurrentProximityHorizontalSeparation[n]**). They are initially separated by 2 000 ft vertically. At some time, the higher aircraft descends at 1 500 ft/min towards the lower aircraft. The scenario is depicted in Figure 32.

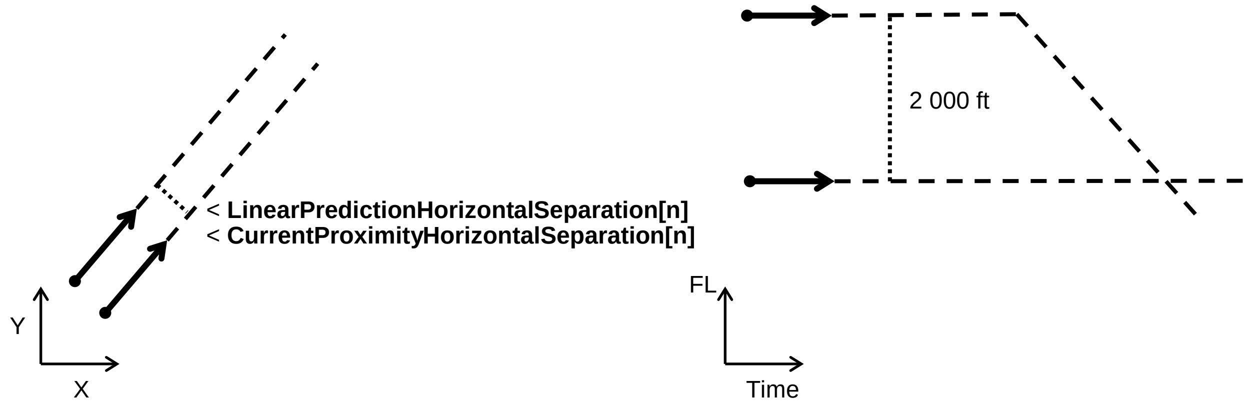


Figure 32: Departure from flight level situation – 2 000 ft test scenario

7.8.3 Target result

Because of the very limited available warning time, STCA must alert as soon as the tracker indicates a vertical manoeuvre towards the next flight level.

Failure to achieve a rapid STCA alert, suggests that the parameters are not properly tuned to take this type of situation into account. A delayed alert may also indicate that the vertical tracker is not optimised to follow such a manoeuvre.

7.8.4 Significant parameters

The following parameters are significant to STCA performance in this scenario:

- **LinearPredictionVerticalSeparation[n,2000]**
- **LinearPredictionImminentTime[n]**
- **LinearPredictionConflictCount[n]**

7.9 Aircraft laterally slow closing on the same flight level

7.9.1 Objective

Aircraft in en route airspace are frequently set on parallel (or almost parallel) headings. This can cause some nuisance alerts, particularly if the aircraft are close to the allowed ATC horizontal separation standard. The objective of this test is to ensure that, in such cases, STCA provides an alert only after some erosion of the ATC separation standard has occurred.

7.9.2 Aircraft geometry

Both aircraft are level at the same flight level and slightly converging headings, in en-route airspace. The scenario is depicted in Figure 33.

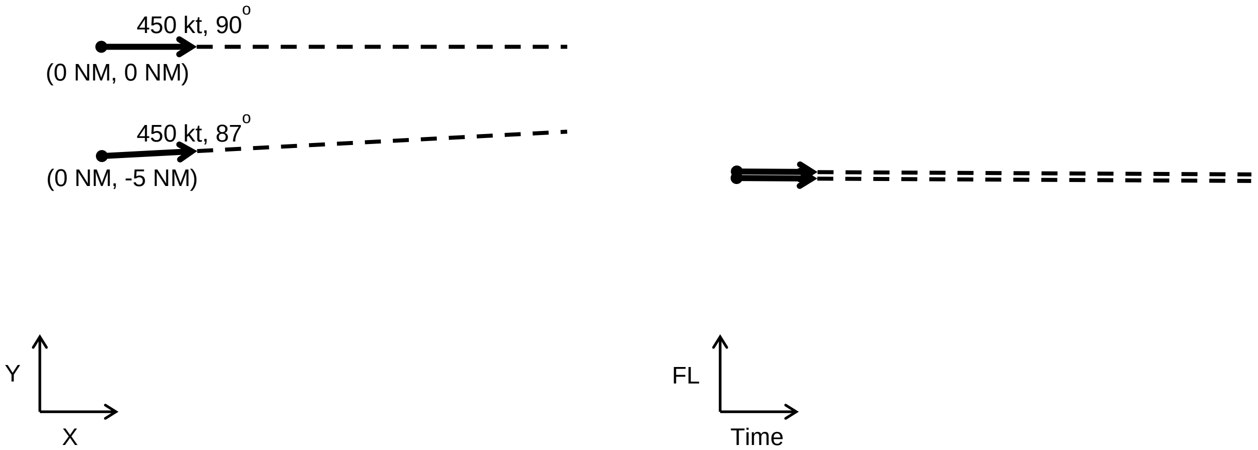


Figure 33: Aircraft laterally slow closing on the same flight level test scenario

With the given speeds and headings, Table 14 provides the expected times of infringing various horizontal separation thresholds:

Table 14: Expected times of infringing various horizontal separation thresholds

Aircraft Separation	Time from Scenario Start
5.0 NM	0 s
4.5 NM	77 s
4.0 NM	153 s
3.5 NM	230 s
3.0 NM	306 s
2.5 NM	383 s

7.9.3 Target result

With such a small rate of convergence, the STCA system must not alert before the 5 NM ATC separation standard has been infringed. Ideally, in this case, the STCA system will allow a small infringement of 4.5 NM, before producing an alarm.

7.9.4 Significant parameters

The following parameters are significant to this scenario:

- **LinearPredictionHorizontalSeparation[n]**

- **LinearPedictionWarningTime[n]**
- **LinearPedictionConflictCount[n]**
- **CurrentProximityHorizontalSeparation[n]**
- **CurrentProximityConflictCount[n]**

7.10 An aircraft levels off at an occupied level (optional input of CFL and/or SFL)

7.10.1 Objective

The objective of these tests is twofold:

- Without use of CFL and/or SFL; STCA can alert soon after the aircraft has levelled off at the occupied flight level
- With use of CFL and/or SFL; The CFL and/or SFL is correctly used for the calculation of the vertical violation interval in the linear prediction filter and leads to an alert well before level off at the occupied level

7.10.2 Aircraft geometry

The scenario is set in TMA airspace below FL290, where 1 000 ft ATC vertical separation applies. The geometry of the situation is arranged so that the horizontal violation is predicted to be over before the vertical violation. The use of CFL and/or SFL (FL150) for one of the aircraft will increase the vertical violation interval and result in an STCA alert before the level-off. Otherwise, the STCA alert should occur soon after the level off. The scenario is depicted in Figure 34.

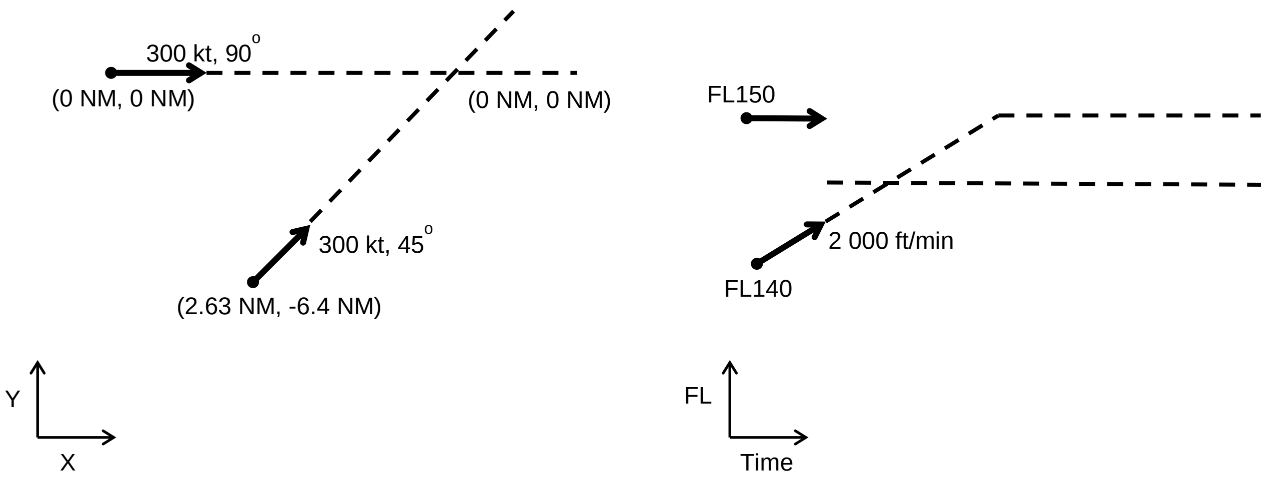


Figure 34: An aircraft levels off at an occupied level (optional input of CFL and/or SFL) test scenario

7.10.3 Target result

Without use of CFL and/or SFL, the STCA system must alert within 3 cycles of the climbing aircraft levelling off.

With use of CFL and/or SFL, it should be possible and is desirable for the STCA system to alert before the aircraft levels off.

7.10.4 Significant parameters

The following parameters are significant to this scenario:

- **UseCFLFlag[n]**
- **UseSFLFlag[n]**
- **LinearPredictionHorizontalSeparation[n]**
- **LinearPredictionVerticalSeparation[n,1000]**

- **LinearPedictionWarningTime[n]**
- **LinearPredictionConflictCount[n]**

7.11 Aircraft climbing and converging vertically

7.11.1 Objective

The objective of this scenario is to test STCA performance when both aircraft are climbing and are also converging vertically into conflict.

7.11.2 Aircraft geometry

The scenario is set in en route airspace where straight courses are more usual than in the TMA. The airspace must be non-RVSM where 2 000 ft ATC vertical separation applies. The aircraft are very close horizontally and remain in permanent horizontal violation (within **LinearPredictionHorizontalSeparation[n]** and **CurrentProximityHorizontalSeparation[n]**). No CFL are used. The scenario is depicted in Figure 35.

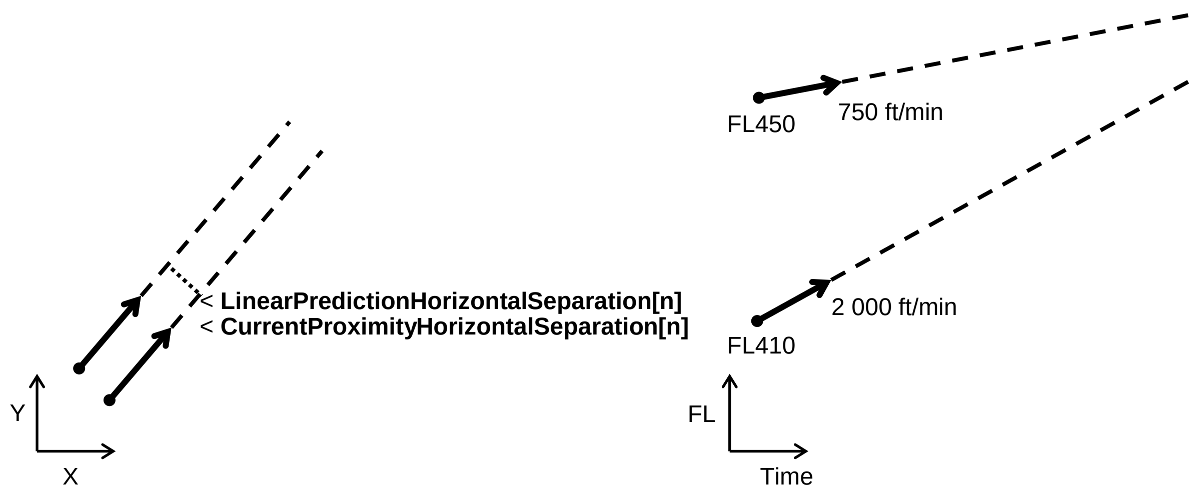


Figure 35: Aircraft climbing and converging vertically test scenario

7.11.3 Target result

STCA must alert at least at t = 122 s before the predicted co-altitude of the tracks (i.e. before t = 70 s into the scenario). In flight level terms, the alert must be given before the aircraft reach FL434 and FL459 respectively.

7.11.4 Significant parameters

The following parameters are significant to this scenario:

- **LinearPredictionVerticalSeparation[n,2000]**
- **LinearPedictionWarningTime[n]**
- **LinearPredictionConflictCount[n]**
- If used, “Time for level off” parameters

7.12 Aircraft proceeds out of exclusion region into imminent conflict

7.12.1 Objective

The objective of this scenario is to test whether STCA generates an alert as soon as an aircraft emerges from an exclusion region into imminent conflict.

7.12.2 Aircraft geometry

This scenario may be located in the TMA or in en route airspace. One aircraft remains in a non-exclusion region. The other aircraft starts in an exclusion region, but then proceeds out of the exclusion region into imminent conflict with the first aircraft. The aircraft remain on the same flight level throughout the scenario. The simulated aircraft are arranged to collide at t = 120 s after the start of the scenario. The scenario is depicted in Figure 36.

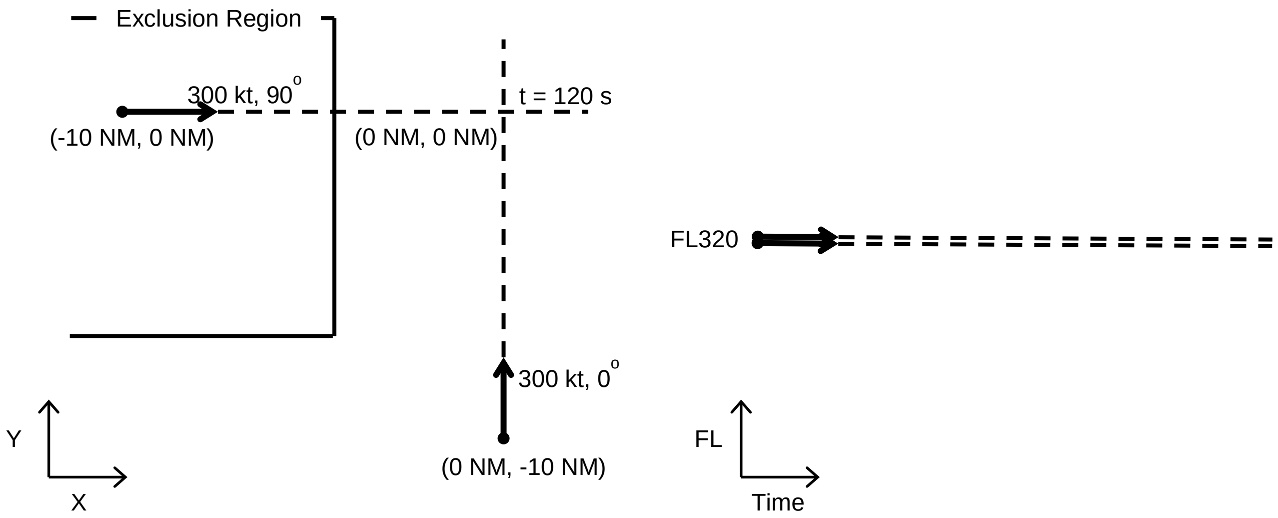


Figure 36: Aircraft proceeds out of exclusion region into imminent conflict test scenario

The aircraft emerges from the exclusion region at t = 70 s into the scenario (50 s to collision). At this time, the separation between the aircraft has reduced to 5.9 NM, one aircraft is at coordinate (-4.167 NM, 0 NM) and the other aircraft is at coordinate (0 NM, -4.167 NM).

7.12.3 Target result

The STCA alert must occur on the first cycle that the aircraft emerges from the exclusion region.

7.12.4 Significant parameters

The following parameters are significant to this scenario:

- **LinearPedictionImminentTime[n]**

7.13 One aircraft turning towards another into conflict

7.13.1 Objective

The objective of this scenario is to test the performance of STCA when one aircraft turns towards another. Note that any STCA system with a turning prediction filter would be expected to perform significantly better in this scenario than one without a turning prediction filter.

7.13.2 Aircraft geometry

Both aircraft are level at the same flight level in a TMA region. Initially one aircraft is on heading 90° and the other aircraft is on heading 180°. At t = 15 s, the first aircraft performs a left turn at 2°/s. The scenario is depicted in Figure 37.

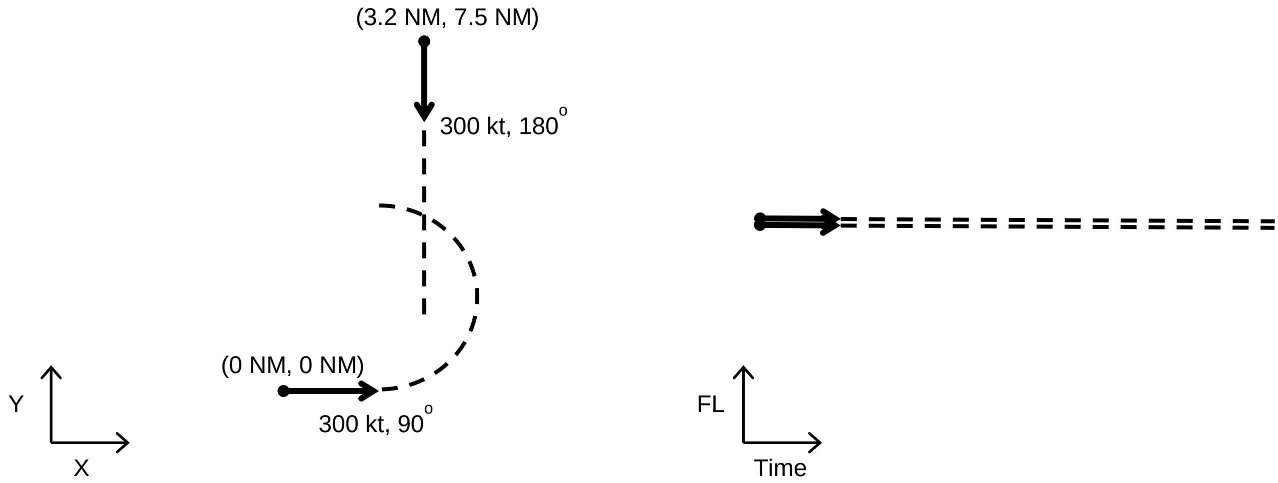


Figure 37: One aircraft turning towards another into conflict test scenario

7.13.3 Target result

If the STCA system does not include a turning prediction filter, then an alert must be generated at or before 45 s into the scenario (at or before t = 30 s into the turn).

If a turning prediction filter is used under option H, an STCA alert must be generated on the first or second turning track update (at or before t = 12 s into the turn)

7.13.4 Significant parameters

The following parameters are significant for STCA systems without a turning prediction filter:

- **LinearPredictionHorizontalSeparation[n]**
- **LinearPredictionConflictCount[n]**
- **LinearPredictionWarningTime[n]**
- **LinearPredictionImminentTime[n]**

The following parameters are significant for STCA systems with the turning prediction filter:

- **TurningPredictionTime [n]**
- **TurningPredictionHorizontalSeparation[n]**
- **TurningPredictionConflictCount[n]**
- **TurningPredictionWarningTime[n]**

7.14 Two aircraft turning towards each other into conflict

7.14.1 Objective

The objective of this scenario is to test the performance of STCA when two aircraft turn towards each other. Note that any STCA system with a turning prediction filter would be expected to perform significantly better in this scenario than one without a turning prediction filter.

7.14.2 Aircraft geometry

Both aircraft are level at the same flight level in a TMA region. Initially one aircraft is on heading 90o and the other aircraft is on heading 270^{o}. At t = 15 s, both aircraft perform a left turn at 2^{o}/s. The scenario is depicted in Figure 38.

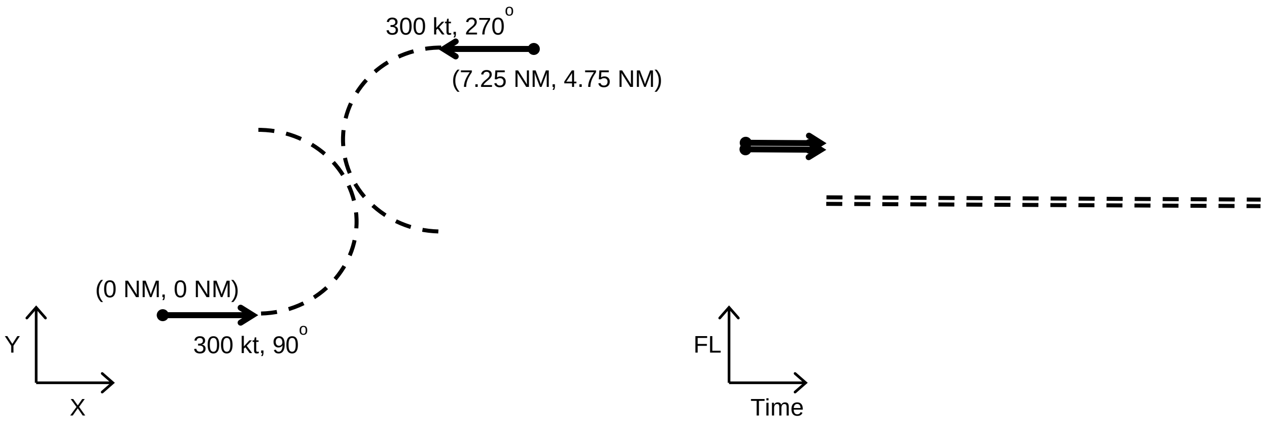


Figure 38: Two aircraft turning towards each other into conflict test scenario

7.14.3 Target result

If the STCA system does not include a turning prediction filter, then an alert must be generated at or before t = 53 s into the scenario (i.e. at or before t = 38 s into the turn).

If a turning prediction filter is used under option H, an STCA alert must be generated on the first or second turning track update (i.e. at or before t = 12 s into the turn).

7.14.4 Significant parameters

The following parameters are significant for STCA systems without a turning prediction filter:

- **LinearPredictionHorizontalSeparation[n]**
- **LinearPredictionConflictCount[n]**
- **LinearPredictionWarningTime[n]**
- **LinearPredictionImminentTime[n]**

The following parameters are significant for STCA systems with the turning prediction filter:

- **TurningPredictionTime [n]**
- **TurningPredictionHorizontalSeparation[n]**
- **TurningPredictionConflictCount[n]**
- **TurningPredictionWarningTime[n]**

7.15 Aircraft cross laterally then cross vertically

7.15.1 Objective

The objective of this scenario is to test STCA performance when two aircraft cross horizontally, then cross vertically. The vertical crossing is initiated when the aircraft are still within the horizontal separation threshold. This manoeuvre quite frequently occurs between arrivals and departures. In this scenario it is a relatively safe manoeuvre because the aircraft are diverging horizontally and have crossed by some distance, even though ATC separation minima are infringed.

7.15.2 Aircraft geometry

The scenario is set in the TMA where crossing arrival and departure traffic is relatively common. The simulated aircraft are arranged to cross at t = 60 s after the start of the scenario at coordinate (0 NM, 0 NM). At t = 80 s, after the aircraft have crossed horizontally, one aircraft climbs from FL60 at 1 500 ft/min, whilst the other aircraft remains on FL70. At this time, the aircraft are diverging horizontally, and separation between them is almost 1.9 NM. Assuming that **LinearPredictionVerticalSeparation[n]** is no greater than 750 ft, the horizontal separation when vertical infringement occurs will be at least 2.8 NM. The scenario is depicted in Figure 39.

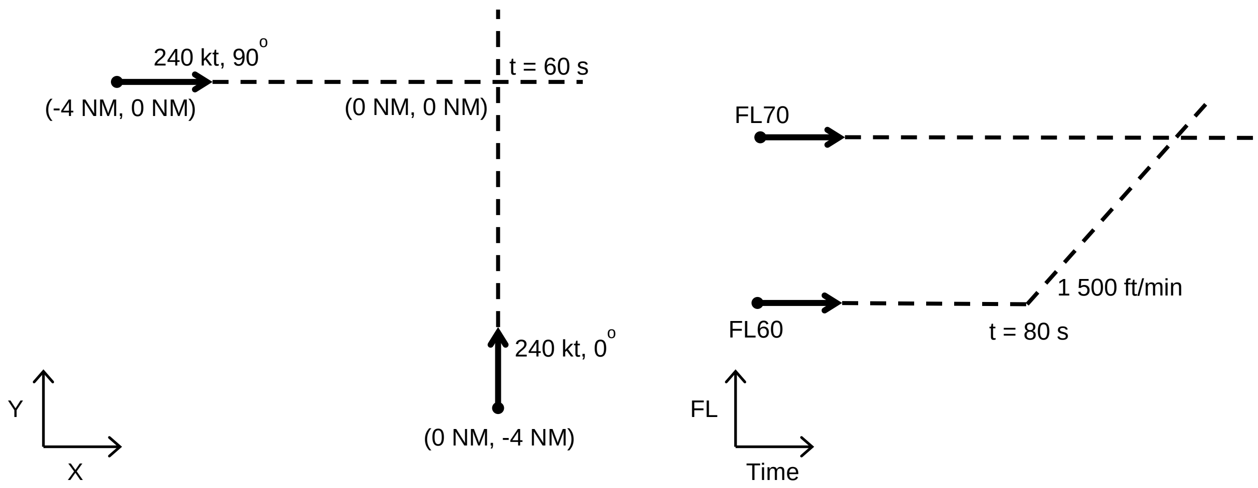


Figure 39: Aircraft cross laterally then cross vertically test scenario

7.15.3 Target result

The situation is relatively safe, and no STCA alert should be generated.

7.15.4 Significant parameters

The STCA result will depend on the following parameters:

- **LinearPredictionHorizontalSeparationDiverging[n]**
- **LinearPredictionVerticalSeparation[n]**

EUROCONTROL

www.eurocontrol.int