

EUROCONTROL Specification for Trajectory Prediction

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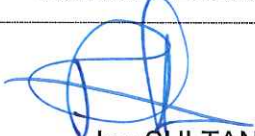

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EXECUTIVE SUMMARY

This EUROCONTROL Specification provides functional and performance requirements for the modelling of flight behaviour in planned and tactical trajectories. This specification is derived from requirements for Air Traffic Control (ATC) tools as specified by the First ATC Systems and Tools Implementation (FASTI) programme, and can be used by air navigation service providers as guidelines in the procurement of FASTI-compliant ATC systems, particularly in support of the SESAR Deployment Programme 2016. This document supersedes the Operational Requirements for EATCHIP Phase III Trajectory Prediction.

The planned trajectory represents a medium-term view of the trajectory of a flight through an area of interest. In this context, the term “medium-term” is often considered to extend from a number of hours before the flight takes place, up to one or two minutes from the current time. The planned trajectory is built initially in accordance with the flight intent, as described by the flight plan, and constrained by ATC procedures. Once the flight is active, the trajectory can be modified by tactical planning and control instructions, and by the integration of flight progress. The planned trajectory is the basis upon which flight data is nominally distributed to the sectors traversed by a flight, coordination is performed between sectors and between ATC units, sector planning and medium-term conflict detection are performed, and upon-which deviation from the planned intent is monitored.

The tactical trajectory provides a short-term view of the trajectory according to the latest tactical clearances given to a flight, without making assumptions on future clearances to be given. The tactical trajectory is used in the detection of conflicts involving aircraft on open clearances – i.e. where a further clearance is required in order for the aircraft to return to its own navigation of the planned intent.

The requirements specified herein fulfil the needs of the Deployment Programme 2016 as they relate to trajectory prediction in en-route and approach ATC ground system, particularly as regards the DP 2016 family 3.2.1 Upgrade of ATM systems (NM, ANSPs, AUs) to support Direct Routings (DCTs) and Free Routing Airspace (FRA), and family 1.2.5 - Implement Advanced RNP routes below Flight Level 310

1 INTRODUCTION

1.1. Purpose

The Single European Sky ATM Research (SESAR) programme is the European Air Traffic Management (EATM) modernisation programme, combining technological, economic and regulatory aspects and using the Single European Sky (SES) legislation to synchronise the plans and actions of the different stakeholders and federate resources for the development and implementation of the required improvements throughout Europe.

The original version of this specification supported, notably, the SESAR ATM Deployment Sequence [SESAR-D4] which described the operational improvements steps that make-up the three implementation phases to achieve SESAR full deployment. Implementation Phase 1, addressing developments in the 2008-2012 timeframe, defines, inter alia, the deployment of “Automated Assistance to ATC Planning for Preventing Conflicts in Enroute Airspace” and “Automated Flight Conformance Monitoring”. In this way, the document specified requirements for trajectory prediction within the context of the SESAR baseline system as defined by [SESAR-D4].

This update of the specification supports the SESAR Deployment Manager’s Deployment Programme 2016 [DP-2016], which provides the project view for full implementation of the Pilot Common Projects (PCP). In particular, [DP-2016] identifies coherent families of implementation activities, underpinning the deployment of the 6 ATM Functionalities in the PCP. The following families are of direct relevance to this specification:

- 1.2.5 - Implement Advanced RNP routes below Flight Level 310;
- 3.2.1 - Upgrade of ATM systems (NM, ANSPs, AUs) to support Direct Routings (DCTs) and Free Routing Airspace (FRA). This document is also consistent with the following essential requirements of Annex II of the Single European Sky (SES) Interoperability Regulation (EC) No 552/2004, as amended by Regulation (EC) 1070/2009:

“The EATMN, its systems and their constituents shall support, on a coordinated basis, new agreed and validated concepts of operation that improve the quality, sustainability and effectiveness of air navigation services, in particular in terms of safety and capacity.”

“Flight data processing systems shall accommodate the progressive implementation of advanced, agreed and validated concepts of operation for all phases of flight, in particular as envisaged in the ATM Master Plan.”

The document also supports the European Single Sky Implementation (ESSIP) objective ATC12.1, for the implementation of automated support for conflict detection, resolution support information and conformance monitoring as well as the ESSIP objectives for Direct Routing (AOM21.1) and Free Route Airspace (AOM21.2).

This specification has been developed and updated in collaboration with operational stakeholders (mainly ANSPs) and ATM ground systems manufacturing industry and will be maintained under the EUROCONTROL Advisory Framework.

The specification may be used by Air Navigation Service Providers (ANSPs) in the planning and procurement of ATM systems that form the SESAR Baseline.

1.2. Scope

This specification covers the calculation of the *trajectory* of a flight from take-off or entry to the *Area of Interest (AoI)* of an Air Traffic Service Unit (ATSU) until landing or exit from the *AoI*, for the purpose of the support of Air Traffic Management (ATM) services and tools.

The *trajectory* is the core information that is used by the system as the basis of distributing flight information to relevant sector work positions and *ATS* units, performing silent coordination and transfer between *sectors* and units, correlating flight data with tracks, assigning a Mode A *SSR* code, monitoring adherence of an aircraft with its assigned *route*, and detecting conflicts in support of sector planning and control (*MTCD*).

Operational requirements for Trajectory Prediction were produced as part of the European Air Traffic Control Harmonisation and Integration Programme (*EATCHIP*) managed by the European Organisation for the Safety of Air Navigation (EUROCONTROL). The *EATCHIP* Operational Requirements Document for TP [*EATM-TP*] specified functional requirements covering the modelling of intent (e.g. “The *planned trajectory* shall be calculated to climb to the *Enroute Cruising Level [ECL]* following restriction [if any] by *strategic constraints*”) and features to achieve accuracy (e.g. “Allowance for the time delays due to turning shall be included in the determination of the trajectory.”). The document also included non-functional requirements covering data granularity, accuracy and response time.

A *FASTI* operational requirements document for trajectory prediction has been developed comprising two volumes, the first based on [*EATM-TP*] but containing only the requirements concerning the modelling of intent, thus suppressing those requirements that dictated how accuracy was to be achieved, and the second describing the required *TP* accuracy.

This specification is derived from the *FASTI* TP Operational Requirements Document [*FASTI-TP*], supplementing it with functionality required by services outside of the *FASTI* scope, and adding additional formality in the form of satisfaction arguments that describe assumptions and domain knowledge that are required for an unambiguous interpretation of the requirement.

1.3. Applicability

These requirements are intended to be used by Air Navigation Service Providers (*ANSPs*) in the planning and procurement of *ATM* systems, particularly those including the *FASTI* controller tools.

As prescribed by the EUROCONTROL Regulatory and Advisory Framework, this document constitutes a voluntary specification. The user of the present document shall be aware that, in the absence of an Implementing Rule concerning Trajectory Prediction, the specification does not confer presumption of conformity to any piece of European legislation; especially, the specification does not by itself ensure compliance with the Essential Requirements of Regulation (EC) 552/2004 as amended by Regulation (EC) N° 1070/2009, which is binding in most of the EUROCONTROL member states.

1.4. Conventions

The term “shall” denotes a mandatory requirement.

The term “should” denotes recommendation or best practice.

The term “may” denotes an optional element.

The term ‘system’ in the context of the requirement refers to any part of the *ATM* automation, without implying any sub-system breakdown.

Requirement sections are preceded with a statement in ***bold italics*** describing the objective that the requirements are intended to fulfil.

1.5. Definitions

Area of Interest

A defined volume of airspace, not constrained by the AoR, within which the flight trajectories are required for any given function to meet the needs of an ATSU.¹

¹ Supersedes definition given in the EUROCONTROL *ATM* Lexicon.

<i>Area of Responsibility</i>	An airspace of defined dimensions within which an <i>ATSU</i> provides air traffic services.
<i>ATC Constraint</i>	A limitation applied to a flight by the <i>ATC</i> organisation.
<i>Cleared Flight Level</i>	The flight level at or to which an aircraft is authorised to proceed under conditions specified by an <i>ATC</i> unit.
<i>Closed Constraint</i>	An <i>ATC constraint</i> that, when applied to a flight, results in a continuous trajectory being maintained throughout the Aol.
<i>Conditional Route</i>	An <i>ATS</i> route or part thereof which can be planned and used under certain specified conditions.
<i>Definite Hold</i>	A hold in which the time at which the flight is expected to leave the holding pattern is known and times at subsequent points can therefore be calculated.
<i>Enroute Cruising Level</i>	The level that the flight is to maintain for a significant part of the flight after reaching <i>TOC</i> and prior to <i>TOD</i> .
<i>Flight Script</i>	A description of the expected behaviour of a flight from the point of view of the controller, given the available information of flight intent and constraints, from which a trajectory can be calculated. ²
<i>Indefinite Hold</i>	A hold in which the time at which the flight is expected to leave the holding pattern is unknown.
<i>Letter of Agreement</i>	A series of constraints and rules that define the agreement entered into by two <i>ATSUs</i> .
<i>Open Constraint</i>	An <i>ATC constraint</i> that, when applied in isolation to a flight, does not allow a continuous trajectory through the Aol to be deduced, another instruction being needed to know the way the flight will resume its normal navigation.
<i>Orbit</i>	A special type of hold constituting a circular path flown from the present position when instructed.
<i>Planned Trajectory</i>	A trajectory representing the most likely behaviour of a flight through an Area of Interest (Aol), from take-off to touch-down, over the medium term. ³
<i>Prior Coordination Airspace</i>	A portion of airspace of defined dimensions within which individual <i>GAT</i> is permitted to fly “off-route” only after prior coordination initiated by <i>GAT</i> controllers with <i>OAT</i> controllers. [EUROCONTROL Handbook for Airspace Management]
<i>Reduced Coordination Airspace</i>	A portion of airspace of defined dimensions within which <i>GAT</i> is permitted to fly “off-route” without requiring <i>GAT</i> controllers to initiate coordination with <i>OAT</i> controllers. [EUROCONTROL Handbook for Airspace Management]
<i>Requested Flight Level</i>	The level requested by the aircraft operator in the flight plan for the <i>segment</i> of the route under consideration. ⁴

² Supersedes definition given in the EUROCONTROL ATM Lexicon.

³ Supersedes definition given in the EUROCONTROL ATM Lexicon.

⁴ Supersedes definition given in the EUROCONTROL ATM Lexicon.

Route	The 2D trajectory of an aircraft, expressed as <i>significant points</i> , <i>ATS routes</i> or geographical points.
Sector	A part of airspace controlled by a team of controllers, defined, notably, by its geographical coordinates, vertical extent and its assigned radio frequency/frequencies. ⁵
Sector Entry/Exit Level	The level agreed between two sector controllers at which an aircraft will be cleared while the aircraft is being transferred between the sectors.
Segment	A part of a route or trajectory defined by initial and terminating points. ⁶
Significant Point	A specified geographical location used in defining an <i>ATS route</i> or the flight path of an aircraft and for other navigation and <i>ATS</i> purposes.
Strategic Constraint	A limitation to the trajectory in order to meet standard <i>ATC</i> procedures.
System Track	A generic entity representing the surveillance data as transmitted by the surveillance system.
Tactical Constraint	An <i>ATC</i> instruction that is issued to a flight or known in advance of such issue for the purpose of tactical control. ⁷
Tactical Trajectory	A trajectory representing the expected behaviour of the aircraft taking into account all clearances and other instructions issued to the aircraft but without making assumptions on subsequent clearances to be issued.
Temporary Reserved Area	A defined volume of airspace normally under the jurisdiction of one aviation authority and temporarily reserved, by common agreement, for the specific use by another aviation authority and through which other traffic may be allowed to transit, under <i>ATC</i> clearance. [EUROCONTROL Handbook for Airspace Management]
Temporary Segregated Area	A defined volume of airspace normally under the jurisdiction of one aviation authority and temporarily segregated, by common agreement, for the exclusive use by another aviation authority and through which other traffic will not be allowed to transit. [EUROCONTROL Handbook for Airspace Management]
Trajectory	A representation of the path of an aircraft, describing the horizontal and vertical profile over time. ⁸

⁵ Supersedes definition given in the EUROCONTROL ATM Lexicon.

⁶ Supersedes definition given in the EUROCONTROL ATM Lexicon.

⁷ Supersedes definition given in the EUROCONTROL ATM Lexicon.

⁸ Supersedes definition given in the EUROCONTROL ATM Lexicon.

1.6. Abbreviations

ABI	Advance Boundary Information (Message Type Designator)
ACC	Area Control Centre
ACT	Activation Message OLDI
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
ANSP	Air Navigation Service Provider
AO	Aircraft Operator
Aol	<i>Area of Interest</i>
AoR	<i>Area of Responsibility</i>
APP	Approach Centre
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
ATSU	Air Traffic Services Unit
CDR	<i>Conditional Route</i>
CFL	<i>Cleared Flight Level</i>
CFMU	Central Flow Management Unit
CPDLC	Controller-Pilot Data Link Communications
CRAM	Conditional Route Availability Message
CTOT	Calculated Take Off Time
DCT	Direct Routing
EATCHIP	European Air Traffic Control Harmonisation and Integration Program
EATMP	European Air Traffic Control Program
ECL	<i>Enroute Cruising Level</i>
EET	Estimated Elapsed Time
EFPL	Extended Flight Plan
EOBT	Estimated Off-Blocks Time
ETFMS	Enhanced Tactical Flow Management System
FASTI	First ATC Support Tools Implementation
FIR	Flight Information Region
FL	Flight Level
FMS	Flight Management System
FPL	Filed Flight Plan
FRA	Free Route Airspace
FUA	Flexible Use of Airspace

GAT	General Air Traffic
HMI	Human-Machine Interface
IAF	Initial Approach Fix
IFPS	Initial Flight Plan Processing System
IFR	Instrument Flight Rules
KPI	Key Performance Indicator
LoA	<i>Letter of Agreement</i>
MSP	Multi Sector Planner
MTCD	Medium-Term Conflict Detection
OAT	Operational Air Traffic
OLDI	Online Data Interchange
PCA	<i>Prior Coordination Airspace</i>
PCP	Pilot Common Project
PEL	Planned Entry Level
RCA	<i>Reduced Coordination Airspace</i>
REV	REVision (Message Type Designator)
RFL	<i>Requested Flight Level</i>
RNAV	Area Navigation
RPL	Repetitive Flight Plan
SES	Single European Sky
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure Route
SSR	Secondary Surveillance Radar
STAR	Standard Terminal Arrival Route
TMA	Terminal Area
TOC	Top Of Climb
TOD	Top Of Descent
TP	Trajectory Prediction
TRA	<i>Temporary Reserved Area</i>
TSA	<i>Temporary Segregated Area</i>
VFR	Visual Flight Rules
VPA	Variable Profile Area
VRC	Vertical Rate of Change
XFL	Exit Flight Level

1.7. Reference Material

[IOP-REG] Regulation (EC) No 552/2004 of the European Parliament and of the Council of

10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation), as amended by Regulation (EC) No 1070/2009 of the European Parliament and of the Council of 21 October 2009 amending Regulations (EC) No 549/2004, (EC) No 550/2004, (EC) No 551/2004 and (EC) No 552/2004 in order to improve the performance and sustainability of the European aviation system

[SESAR- D4]	SESAR D4 – The ATM Deployment Sequence, January 2008
[CONOPS]	FASTI Operational Concept, Edition 1.1, 20 March 2007
[FASTI-TP]	FASTI Operational Requirements for Trajectory Prediction, Edition 1, 4 November 2008
[EATM-TP]	Operational Requirements for EATCHIP Phase III Trajectory Prediction, Edition 1.1, 28 May 1999
[PANS-ATM]	Procedures for Air Navigation Services – Air Traffic Management, ICAO Document 4444, Fourteenth Edition dated 1 November 2001, as amended.
[IFPS-DOM]	IFPS and RPL Dictionary of Messages, Edition 2.002
[SUR-STD]	Radar Surveillance Standard for Enroute and Major Terminal Areas – SUR.ET1.ST01.1000-STD-01-01, Edition 1.0, 1 March 1997
[MET-ATM]	EATMP - Met Data in ATM – Final Report, Edition 1, December 2005
[DP-2016]	SESAR Deployment Manager – Deployment Programme 2016, 30 September 2016
[MONA-SPEC]	EUROCONTROL Specification for Monitoring Aids, Edition 2.0
[ASM-HB]	European Route Network Improvement Plan (ERNIP) – Part 3 – The ASM Handbook, Edition 5.3, November 2016

1.8. Document Structure

This specification contains four chapters as follows:

Chapter 1 (this chapter) provides an introduction to the specification, describing the purpose, scope, applicability, and conventions used, defining acronyms and terms used within the specification and identifying reference documents.

Chapter 2 gives an overview of the Trajectory Prediction service, describing the context, classes of trajectory and logical breakdown.

Chapter 3 provides the functional requirements of the Trajectory Prediction service.

Chapter 4 provides accuracy requirements for the planned and tactical trajectories.

2 TRAJECTORY PREDICTION OVERVIEW

2.1. Context

The context of trajectory prediction within the SESAR baseline system is depicted in Figure 1, below.

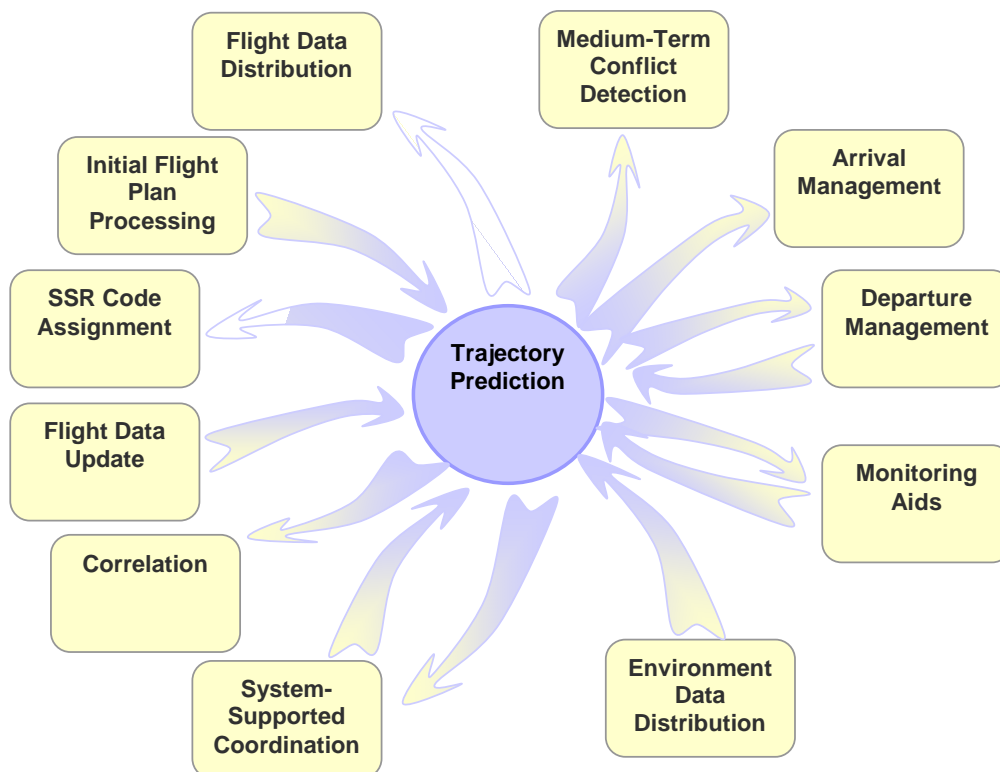


FIGURE 1 - TRAJECTORY PREDICTION CONTEXT

The interaction with the external entities is described as follows:

Flight Data Distribution – flight data is distributed to sector work positions on the basis of sectors identified as being traversed by the trajectory;

Initial Flight Plan Processing – trajectories are created and amended during the flight planning phase on the basis of messages received from the Initial Flight Plan Processing System (IFPS) and from manual input by flight data operators;

SSR Code Assignment – a Mode A SSR code is assigned to the flight on the basis of the planned route and the code allotment plan (planned for centralized assignment in the future);

Flight Data Update – once the flight is active, the trajectory is amended according to *tactical constraints* (clearances and sector planning instructions) entered by the controllers;

Correlation – flight data is correlated with a corresponding *system track* on the basis of the Mode A SSR code and the planned route;

System-Supported Coordination – coordination is performed automatically between sectors and with external units on the basis of sector boundary conditions contained in the trajectory; the trajectory is also amended by sector boundary conditions received from external units;

Environment Data Distribution – information on aeronautical elements (e.g. navigation aids, ATS route identifiers, etc) referenced in flight plan messages is obtained in order to decode the *planned route*; aircraft performance is adapted according to forecast meteorological conditions; standard ATC procedures and *Letters of Agreement* constrain the trajectory; intersections of the trajectory with defined airspace elements (e.g. special use airspace, sectors, etc) are identified;

Monitoring Aids – deviation warnings and automatic reminders (e.g. time to transfer) are provided to the controller on the basis of the horizontal route and estimated times at certain waypoints respectively defined by the *trajectory*; the *trajectory* is updated with actual progress in the longitudinal and vertical dimensions as determined from the correlated *system track*;

Medium-Term Conflict Detection – aircraft-aircraft conflicts, for planning and tactical support, are identified where the calculated separation between two flights, obtained by deriving their position at a moment in time from the *trajectory*, infringes defined separation criteria; similarly, aircraft-airspace and aircraft-terrain conflicts are identified where the separation between a flight and restricted airspace or terrain infringes defined criteria.

Arrival Management – an optimized sequence of flights is generated together with advisory information on time to lose or gain for each flight in order to avoid bunching. The Arrival Manager might assign the runway to landing flights.

Departure Management – optimizes the sequence of departure flights and might assign the departure runway.

2.2. Classes of Trajectory

Two classes of *trajectory* are defined, termed the “*Planned Trajectory*” and the “*Tactical Trajectory*”, which together address the diverse needs of the envisaged clients of the *TP*. For each class of *trajectory*, there might be an active *trajectory* together with a number of tentative trajectories simulating possible new clearances (“what-if”).

The “*Planned Trajectory*” represents the most likely behaviour of a flight through an Area of Interest (AoI), from take-off to touch-down, over the medium term.

The behaviour of the flight is derived from the planned *route* (preferable beyond AoR boundaries) and requested vertical profile, ATC procedures, inter-sector coordination, tactical instructions in which the further *trajectory* beyond the clearance is known (i.e. “*closed constraints*”), and the current aircraft state (position and velocity).

The *planned trajectory* represents the stable medium to long term behaviour of the aircraft but may be inaccurate over the short term where tactical instructions issued to achieve the longer term plan are unknown or a probable *trajectory* has been calculated on the basis of assumptions of expected short term behaviour.

The “*Tactical Trajectory*” represents the expected behaviour of the aircraft taking into account all clearances and other instructions issued to the aircraft but without making assumptions on subsequent clearances to be issued.

The purpose of the *tactical trajectory* is to enable the identification of conflicts that would occur in the absence of further tactical instructions – i.e. if the aircraft were left on their current clearances. It is useful for a relatively short prediction horizon, (e.g. 5-10 minutes) after which it is expected that further known tactical instructions would have been issued.

2.3. TP Logical Breakdown

The trajectory prediction process is often considered to comprise two steps; firstly, an *intent engine* derives an unambiguous description of how the aircraft is to be operated (termed “*aircraft intent*”) from flight state and intent, and secondly a *trajectory engine* calculates the motion of the aircraft by means of an aircraft performance model. With such a breakdown, the performance of a trajectory engine can be determined by comparison with actual aircraft motion, often approximated with the *FMS*, by subjecting both to the same aircraft intent and environmental conditions. However, when determining overall trajectory prediction accuracy, both the trajectory engine and the intent engine must be considered.

The intent engine builds the aircraft intent from a mixture of declared items of flight state and intent (e.g. the flight plan, ATC procedures, clearances, etc) and undeclared items (e.g. operator thrust/speed regimes). Consequently, assumptions and approximations have to be made by the trajectory predictor to conjecture the undeclared items.

As described above, the specification of the requirements for the calculation of the *trajectory* is in two parts; the first, this part, describes the rules for building the *flight script* in so much as it relates to declared items of state and intent; the second part specifies the required accuracy of the calculation, accounting both for filling the missing parts of the *flight script* and modelling the aircraft motion by the trajectory engine.

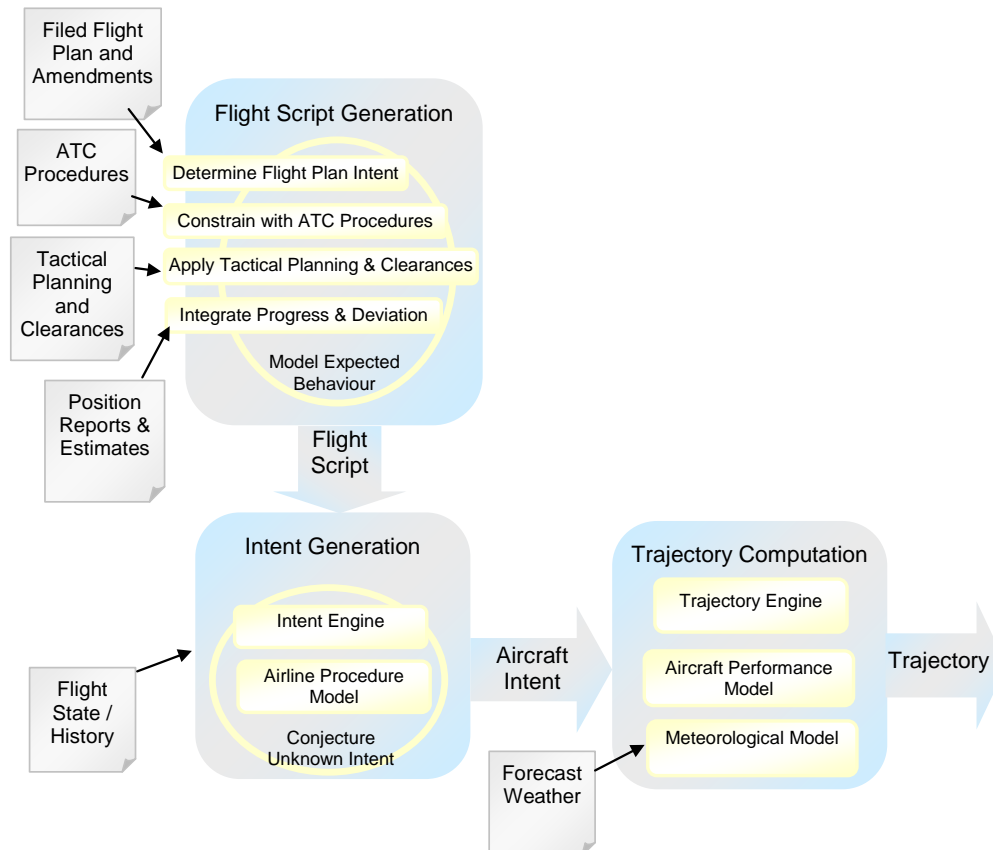


FIGURE 2 - LOGICAL TP BREAKDOWN

Therefore, this specification describes rules that govern how the *trajectory* is built according to intent and state information as it is known to the system. In addition to the main *flight script* corresponding to the current plan, a number of alternative *flight scripts* might be created as a means to test the effects of re-clearing or re-planning the aircraft.

Performance requirements specify the level of accuracy to be achieved, on the assumption that the aircraft is cleared in conformance with the *flight script* and the aircraft is operated as cleared.

The characteristics and algorithms for achieving the required accuracy in the modelling of the aircraft motion is considered a matter of system design, encompassing both the derivation of items of aircraft intent that might not be described in the *flight script* (e.g. aircraft take-off weight, aircraft operational procedures), and the modelling of aircraft performance. It is likely that this would be achieved by means of “knowledge banks”, populated either by published information or through observation, and possible algorithms to model the laws of motion and to synthesize actual behaviour with the prediction.

3 FUNCTIONAL REQUIREMENTS

3.1. Flight Intent

3.1.1 Sources of Flight Intent

The system determines the flight intent from a filed flight plan and subsequent amendments.

- 3.1.1.1 The system **shall** extract the aircraft type, aerodromes of departure and destination, EOBT, EET, flight rules, requested level, speed and *route* from the corresponding fields of the filed flight plan and amendments and from manual input.

3.1.2 Route Extraction

The system determines the planned horizontal path through the Area of Interest.

- 3.1.2.1 The system **shall** recognize route elements expressed as *ATS* route identifiers, *significant point* identifiers, coordinates, and offset from a *significant point*, as described in ICAO Document 4444 [PANS-ATM], including recognition of LAT/LONG waypoints
- 3.1.2.2 The system **may** extract the route from the IFPS expanded route (RTEPTS).
- 3.1.2.3 The system **may** extract the route from Extended Flight Plan (EFPL) provided by IFPS.
- 3.1.2.4 The system **shall** compile a sequenced list of points corresponding to *route* elements in the flight plan that match elements defined in the *AoI* environment data.
- 3.1.2.5 The system **may** compile a sequenced list of points corresponding to *route* elements in the flight plan beyond the *AoI* boundaries.
- 3.1.2.6 For *route* elements that correspond to *route* points defined in the environment data, the system **shall** insert the point in the *route* point list.
- 3.1.2.7 The system **should** dismiss single recognized route points that are preceded and succeeded by unrecognized route elements.
- 3.1.2.8 For *route* elements expressed as coordinates, the system **shall** insert the point in the route point list if the coordinates are within the *AoI*.
- 3.1.2.9 For a *route* element that corresponds to a defined *ATS route*, where the preceding and succeeding elements correspond to *route* points on that *ATS route* defined in the environment data, the system **shall** insert the points defined for the *ATS route* between the two specified *route* points, in the *route* point list.
- 3.1.2.10 In cases where an *ATS route* name element appears either before the first, or after the last recognized *route* point element, the system **may** insert the *route* points that correspond to the direction of travel along the *route* from/to the *AoI* boundary.
- 3.1.2.11 For direct routing segments, the system **shall** model the great-circle path between the segment end points, inserting intermediate points if necessary.
- 3.1.2.12 Where the first *route* element corresponds to a *SID* that is defined for the aerodrome of departure and whose end point corresponds to the next *route* element, the system **may** insert the points defined for the *SID* in the *route* point list.
- 3.1.2.13 Where the last *route* element corresponds to a *STAR* that is defined for the aerodrome of arrival and whose start point corresponds to the previous *route* element, the system **may** insert the points defined for the *STAR* and, if defined, the instrument approach procedure, in the *route* point list.
- 3.1.2.14 Where a flight re-enters an *AoI*, the *route* through the *AoI* **shall** be determined for each traversal.

- 3.1.2.15 The system **should** verify that the route elements of a flight are valid on the date of flight according to their validity period.

3.1.3 Speed and Level Extraction

The system determines the planned speed and level profile within the AoI.

- 3.1.3.1 The system **shall** identify the last requested level prior to entering the AoI as the initial enroute cruising level (ECL) in the AoI.
- 3.1.3.2 The system **shall** identify the last requested speed/mach number prior to entering the AoI as the initial requested speed in the AoI.
- 3.1.3.3 The system **shall** identify requested level and/or speed modifiers in route elements within the AoI.

3.1.4 Intent Consistency

The system ensures that the flight intent is consistent with the airspace and aircraft type.

- 3.1.4.1 In case of an unrecognized route element (i.e. does not match elements defined in the environment data) within an IFR portion of the route in the AoI, the system **shall** refer the flight plan for manual correction.

NOTE: A complete and continuous description of the flight intent is required for controlled portions of the route through the AoI. Therefore, once the entrance of a filed IFR route into the AoI is located by matching point and route name identifiers with those described in the environment data, each subsequent element must also be recognized until the exit of the AoI is located.

- 3.1.4.2 In case of inconsistencies between route elements (significant point and ATS route, SID and departure aerodrome, STAR and destination, etc) within the AoI portion of the route, the system **shall** refer the flight plan for manual correction.
- 3.1.4.3 In case of unachievable speed or level elements for the aircraft type, the system **shall** highlight the flight for manual attention.

3.2. ATC Procedures and Strategic Constraints

3.2.1 Departures

A SID or preferential departure route is assigned to a flight, where applicable, before departure.

- 3.2.1.1 An assigned departure runway for a flight **shall** override any previously entered or default departure runway.
- 3.2.1.2 An assigned SID or preferential departure route for a flight **shall** override any automatically assigned, previously entered or filed SID preferential departure route providing it is consistent with the departure runway and route.
- 3.2.1.3 Where a valid SID or preferential departure route has not been filed or assigned for a flight, the system **may** assign a SID or preferential departure route, if one is defined, according to the departure runway, aircraft category, time of departure, SID or preferential departure route status and filed route.
- 3.2.1.4 In cases where a valid SID or preferential departure route has not been filed or assigned and a valid SID or preferential departure route can not be determined automatically, the system **may** derive the departure route as direct from the runway to a filed fix and/or refer the flight for manual handling.

3.2.2 Arrivals

A STAR or preferential arrival route is assigned to a flight, where applicable, prior to commencing its approach.

- 3.2.2.1 An assigned arrival runway for a flight **shall** override any previously entered or default arrival runway.
- 3.2.2.2 An assigned STAR or preferential arrival route for a flight **shall** override any automatically assigned, previously assigned or filed STAR or preferential arrival route providing it is consistent with the arrival runway and *route*.
- 3.2.2.3 Where a valid STAR or preferential arrival route has not been filed or manually assigned for a flight, the system **may** assign a STAR or preferential arrival route, if one is defined, according to the arrival runway, aircraft category, time of arrival, STAR or preferential arrival route status and filed *route*.
- 3.2.2.4 In cases where a STAR or preferential arrival route has not been filed or manually assigned and a valid STAR or preferential arrival route can not be determined automatically, the system **may** derive the arrival route as direct from a filed fix to the runway and/or refer the flight for manual handling.

3.2.3 Strategic Constraints

The system applies strategic constraints corresponding to normal ATC procedures.

- 3.2.3.1 The system **shall** select constraints applicable to a flight by matching the following elements, individually or in combination as defined by the constraint:
 - departure aerodrome;
 - destination aerodrome;
 - *significant point*;
 - *ATS route*;
 - crossing a defined constraint line;
 - penetration of a designated area.
- 3.2.3.2 The restriction in level/speed to be applied **shall** be selected by comparison of the *enroute cruising level* or the requested flight level with respective thresholds defined for each restriction.
- 3.2.3.3 According to the definition of the selected restriction, the system **should** be capable of applying a restriction at a specified distance before or after the constraint point or line.
- 3.2.3.4 According to the definition of the selected restriction, the system **shall** limit the level and/or speed at the constraint point or line to the level/speed defined by the restriction.
- 3.2.3.5 According to the definition of the selected restriction, the system **may** limit the vertical speed at the constraint point or line to the vertical speed defined by the constraint.
- 3.2.3.6 Upon creation, amendment or cancellation of a strategic constraint, the system **shall** recalculate all trajectories impacted by the constraint.

3.2.4 Conditional Routes

The system ensures that any planned traversal of a closed conditional route is notified to the controller.

- 3.2.4.1 A warning indication **shall** be given to the flight if a trajectory traverses a category 1 or 2 CDR at a level at which it is planned to be closed during the traversal and there is no applicable alternative route.

- 3.2.4.2 If a trajectory traverses a category 1 or 2 *CDR* at a level at which it is planned to be closed during the traversal, an alternative route **should** be applied automatically if available.
- 3.2.4.3 If an alternative *route* is automatically inserted into the *route*, a warning **shall** be generated.

The system identifies category 3 CDRs that are available to shorten a planned route.

- 3.2.4.4 The system **should** automatically apply a *CDR* to a flight route if the *CDR* end points match waypoints in the route, and the *CDR* is planned to be available at the time and level at which it is traversed by the *trajectory*.
- 3.2.4.5 If a *CDR* is automatically inserted into the *route*, a warning **shall** be generated.

3.2.5 Area Crossing Restrictions

The system ensures that direct route segments that traverse active TSAs or TRAs are referred for manual action.

- 3.2.5.1 The system **shall** provide a warning indication to a flight if it contains direct route segments through active *TSAs* or *TRAs* for manual correction.
- 3.2.5.2 On controller request, the system **should** propose an alternative *trajectory* that avoids an active *TSA* or *TRA*.
- 3.2.5.3 Where a *route* amendment is entered locally that would result in a direct (off-ATS) *route* across an active *TSA* or *TRA*, a warning indication **shall** be given to the flight and confirmation required before the resultant *trajectory* becomes the active *trajectory*.

The system determines penetrations of PCAs and RCAs necessary to support the civil/military coordination process.

- 3.2.5.4 The system **may** identify route segments that traverse *PCAs* and *RCAs* in order to support civil/military coordination.

3.2.6 Sector Computation

The system determines sector penetrations and coordination points necessary to support the sector control sequence.

- 3.2.6.1 The system **shall** determine the sequence of sectors through the AoR traversed by a flight.
- 3.2.6.2 In case of multi-sector planning, the system **shall** determine the entry and exit details of the multi-sector area.
- 3.2.6.3 The system **shall** determine each coordination point in the trajectory either by explicit reference to a point in the trajectory to a predefined coordination point or, if none exists (e.g. in the case of DCT or transition between layered sectors), either as a predefined coordination point close to the sector boundary point or as the sector boundary point (either as latitude & longitude or range & bearing from a predefined point)
- 3.2.6.4 Where flights operating as OAT are controlled from designated OAT sectors, the system **may** determine the sequence of OAT sectors and coordination points through the AoR traversed by OAT portions of the flight.
- 3.2.6.5 The system **may** determine sectors and/or ATS units to be notified of a flight according to the penetration of predefined airspace volumes.
- 3.2.6.6 Where multiple sectors are defined covering the same airspace, the system **may** determine the sector to control the flight by matching departure and/or destination aerodrome with the criteria defined by the sector.

3.3. Tactical Constraints Application

3.3.1 Sector Entry/Exit Conditions

When coordination is between horizontally-adjacent sectors, an entered entry/exit level is applied as a constraint on the entry/exit coordination point and the trajectory recalculated.

- 3.3.1.1 The system **shall** apply an entered *sector entry/exit level* as a constraint on the respective coordination point, providing that the coordination is between horizontally-adjacent sectors.
- 3.3.1.2 Where a flight is between *TOC* and *TOD* at the AoR entry coordination point, the *ECL* after the coordination point **may** be set to the value of the *entry level*, thus propagating the *entry level* downstream.
- 3.3.1.3 Upon entry of a new *entry/exit level*, the system **shall** re-evaluate the flight for strategic constraints as described in section 3.2.
- 3.3.1.4 The level specified in an Oceanic Clearance, if available, **shall** override the default *XFL* for the *sector* from which a flight enters the Oceanic Control Area.
- 3.3.1.5 Where an *entry/exit level* might be used for coordinating between horizontally-adjacent sectors or between layered sectors, the system **shall** allow the transferring controller to specify the next *sector* and/or the point at which the *XFL* is to be applied.

3.3.2 Enroute Cruising Level (ECL)

Upon entry of a new ECL, the trajectory is modelled climbing or descending at the specified point if entered, otherwise from the current aircraft position, to the new ECL.

- 3.3.2.1 Upon entry of a revised *ECL*, the new *ECL* **shall** overwrite the previous *ECL* from the point at which the change is to take place if specified, or from the present aircraft position if the flight is in the sector, or from the sector entry point.
- 3.3.2.2 The system **shall** re-assess *strategic constraints* in the presence of the new *ECL*.

3.3.3 Cleared Flight Level (CFL)

If, during the climb or descent phases, a flight is cleared beyond the level of the currently applicable strategic constraint, the constraint is bypassed, the climb/descent continuing to the next constraint.

- 3.3.3.1 If the *CFL* of a flight before *TOC* is above the level applicable before the expiry of any current or subsequent strategic level constraint, the constraint is ignored and the *planned trajectory* **shall** be calculated to climb to the *ECL* or the next *strategic constraint*, as applicable.
- 3.3.3.2 If the *CFL* of a flight after *TOD* is below the level of any current or subsequent strategic level constraint, the constraint is ignored and the *planned trajectory* **shall** be calculated to continue descent to the next *strategic constraint* level.
- 3.3.3.3 Once an aircraft has started its descent, entry of a new *CFL* **should** cause the trajectory to model the descent immediately to the new *CFL*.
- 3.3.3.4 Where the entry of a *CFL* causes a *strategic constraint* to be overwritten, the system **may** provide a warning indication on the flight.
- 3.3.3.5 The system **should** re-assess overall strategic constraints in the presence of the new *CFL*.

3.3.4 Vertical Rate of Change (VRC)

An entered expedite, minimum or maximum VRC is applied to the trajectory from the current level of the aircraft to the CFL if the currently applied VRC is outside the specified limit.

- 3.3.4.1 Where an expedited climb or descent is issued, a predefined increased VRC **shall** be applied to the *planned trajectory*.
- 3.3.4.2 An entered minimum VRC (i.e 'climb/descend at [xxx] minimum') **shall** be applied to the *planned trajectory* if the currently applied VRC is below the specified minimum rate.
- 3.3.4.3 An entered maximum VRC (i.e 'climb/descend at [xxx] maximum') **shall** be applied to the *planned trajectory* if the currently applied VRC is above the specified maximum rate.
- 3.3.4.4 Where an absolute rate of climb or descent is issued, the VRC **shall** be applied to the *planned trajectory*.

3.3.5 Hold

The system incorporates entered holding instructions in the trajectory.

- 3.3.5.1 Where an *indefinite hold* is applied, absolute time values for points on the *planned trajectory* **may** be terminated beyond the holding point.
- 3.3.5.2 Where the hold is definite, points on the *planned trajectory* beyond the holding point **shall** utilise the hold exit time.
- 3.3.5.3 When a hold restriction is removed the *planned trajectory* **shall** be determined from the current location of the flight to the next point on the *route*.
- 3.3.5.4 The vertical profile beyond the holding point **shall** be constructed according to strategic constraints defined for the holding point and the further route (if any), irrespective of the entry level to the hold.

3.3.6 Assigned Heading or Track

On entry of an assigned heading, the route is modified from the current aircraft position, following the derived ground track for the likely duration of the clearance, and subsequently turning to rejoin the original route.

- 3.3.6.1 Upon entry of an assigned heading or track with a controller-entered duration (e.g. in the form of next turn point), the system **shall** model the turn, inserting the next turn point corresponding to the entered duration and discarding the *route* points between the point from which the heading is to be applied and the *route* rejoining fix.
- 3.3.6.2 In cases where an assigned heading or track is entered without specifying the duration, the system **may** determine a probable duration according to defined parameters.
- 3.3.6.3 In cases where an assigned heading or track is entered without an explicit *route* joining fix, the system **may** determine the probable *route* rejoining fix as the first fix yet to be passed that requires a heading change less than a defined amount.
- 3.3.6.4 Following entry of an assigned heading or track, strategic constraints **shall** be reassessed.
- 3.3.6.5 If an assigned heading or track spans a *sector* boundary, any *entry/exit level* constraints corresponding to the crossed *sector* boundaries **shall** be maintained and assigned to the new boundary crossing points.
- 3.3.6.6 When an assigned heading or track is terminated, the *planned trajectory* **shall** be recalculated including the *segment* from the current position of the flight to the specified point, if entered.

- 3.3.6.7 In cases where an assigned heading or track is terminated without an explicit *route* joining fix, the system **may** determine the probable *route* rejoining fix as the first fix yet to be passed that requires a heading change less than a defined amount.

3.3.7 Assigned Speed

An assigned speed is applied to the trajectory until the conditions for termination apply.

- 3.3.7.1 Where an airspeed constraint is entered and the speed used in the calculation of any part of the *planned trajectory* to which the constraint applies is not compliant with the constraint, the *planned trajectory* **may** be recalculated to comply with the constraint.
- 3.3.7.2 Where the termination conditions for an assigned speed are not specified, the assigned speed for a flight in climb or descent **may** be maintained until the point at which the *CFL* is reached or until the speed is no longer compatible with the aircraft performance.
- 3.3.7.3 Upon termination of a speed constraint, the *planned trajectory* **shall** be recalculated without the speed constraint speed.

3.3.8 Assigned Route or Direct

An assigned route replaces the original route between the specified start and end points and the new planned trajectory is calculated.

- 3.3.8.1 If a *route* amendment or diversion starts at a point on the *route* of flight beyond the present position on the *planned trajectory*, the entered *route* data **shall** replace all or part of the original *route* from the specified point.
- 3.3.8.2 If a *route* amendment, diversion or direct clearance starts at the present position of the system track, the entered *route* **shall** replace the *route* from the present (current) position of the system track.
- 3.3.8.3 For uncorrelated flights, a route amendment or diversion **may** be applied from the estimate present position derived from the planning trajectory.
- 3.3.8.4 With respect to the last entered *route* element, the amended *route* data **shall** either regain the original *route* at the point or replace the original *route* as specified in the input data.
- 3.3.8.5 Following entry of route amendment or diversion, strategic constraints **shall** be reassessed.
- 3.3.8.6 If a route amendment or diversion spans a sector boundary, any entry/exit level constraints corresponding to the crossed sector boundaries **shall** be maintained and assigned to the new boundary crossing points.
- 3.3.8.7 When a *route* amendment is entered by reference to *significant points* and *ATS* routes, the resultant *route* description **shall** be checked for correctness.
- 3.3.8.8 If the *route* resulting from the entry of a *route* amendment is error free, a new *planned trajectory* **shall** be calculated.
- 3.3.8.9 In case of DCT or FRA, the system **shall** be capable of calculating a direct (great-circle) route to any point within the DCT/FRA.
- 3.3.8.10 The system **shall** provide an editing function to allow the creation, amendment and removal of waypoints and associated level and time constraints within the *AoI*. (*AoI* might need to be extended for FRA clearances)

3.3.9 Missed Approach Processing

The system determines the trajectory of a flight performing a missed approach procedure.

- 3.3.9.1 Upon manual input or automatic detection of a missed approach, a *planned trajectory* **may** be determined for the flight using the published missed approach procedure.

3.3.10 Tactical Parallel Offset

The system applies entered tactical parallel offset clearances, if provided, to the planned trajectory.

- 3.3.10.1 Upon entry of a tactical parallel offset clearance, a *route* parallel to the original *route*, offset by a predefined distance, **may** be applied in the *planned trajectory*.
- 3.3.10.2 The path from the original route to start a parallel offset **may** commence either at a specified point (if entered) or at the current aircraft position (if between the *SID* and the *STAR*) or at the end point of the *SID*.
- 3.3.10.3 The path from the tactical offset to rejoin the original route **may** terminate either at a specified point (if entered) or at the last point prior to the *STAR* (if within the *AoR*) or at the *AoR* exit coordination point.
- 3.3.10.4 Following entry of a tactical parallel offset, *strategic constraints* **shall** be re-assessed.
- 3.3.10.5 If a tactical parallel offset spans a sector boundary, any entry/exit level constraints corresponding to the crossed sector boundaries **shall** be maintained and assigned to the new boundary crossing points.

3.3.11 Time Constraints

The system applies entered time constraints to the trajectory.

- 3.3.11.1 When a time constraint is applied at a point that is different from the current calculated time at the point, a change of airspeed within the normal operating envelope and without any additional level change **shall** be applied in order to attempt to comply with the constraint if possible.
- 3.3.11.2 If a *planned trajectory* cannot be determined that complies with a time constraint, a *planned trajectory* **shall** be determined that attempts as far as possible to comply with the constraint and a warning issued of the remaining time to lose.

3.4. Climb and Descent Rules

The profile is modelled on the assumption that the aircraft will climb as early as possible and descend as late as possible to meet its constraints.

- 3.4.1.1 The *planned trajectory* **shall** be calculated to climb from the previous constraint application point (if any), departure aerodrome or *AoI* entry point to the next constrained level (if any) or Enroute Cruising Level (ECL) until reaching the ECL.
- 3.4.1.2 The descent profile **shall** be determined for flights arriving within the *AoI* and for those arriving outside the *AoI* for which a *strategic constraint* relating to the descent to the destination aerodrome exists.
- 3.4.1.3 The *planned trajectory* **shall** be calculated to descend to reach the next constrained level at the respective constraint application point (if any) or to the arrival aerodrome.
- 3.4.1.4 The enroute portion of the *planned trajectory* **shall** be determined from *TOC* until *TOD* maintaining the *enroute cruising level* and any changes to it.

If, in order to meet a constraint, a climb or descent performance is required above the normal performance but within the performance envelope of the aircraft, the climb/descent is modelled assuming that the constraint will be achieved.

- 3.4.1.5 When a constraint cannot be met by following the default performance profile, the *strategic constraint* **shall** be met by applying the necessary aircraft performance within a predefined permitted performance range.
- 3.4.1.6 When a constraint cannot be met within the achievable performance values, a warning **should** be generated.

3.5. Integration of Progress and Deviation

The trajectory is recalculated using the most recent timing and progress information when this becomes available.

- 3.5.1.1 Estimated times in the *planned trajectory* that are derived from estimates in the flight plan **shall** be superseded by estimates and regulations issued by *ETFMS*, if available.
 - 3.5.1.2 Estimated times obtained in notification and coordination messages and in manually-entered estimates **shall** be applied to the *planned trajectory* except in cases where progress is being updated through the monitoring aids.
 - 3.5.1.3 The *planned trajectory* **shall** be updated with the actual progress of the aircraft.
 - 3.5.1.3.a The system **may** use the measured ground speed to update the planned trajectory
- The climb and descent profiles are recalculated according to the actual manoeuvres performed by the aircraft.*
- 3.5.1.4 If a climbing flight approaches within a defined distance of its *CFL* then the *planned trajectory* **may** be levelled out for a defined distance or time before resuming the climb.
 - 3.5.1.5 When a flight starts to descend towards its cleared level before the calculated *TOD*, the descent to the *CFL* **may** be modelled from the current position of the aircraft.

The flight path of an aircraft having been instructed to turn is corrected for effects of turn delay and wind drift once the turn is completed.

- 3.5.1.6 Once an aircraft that has been instructed to turn has completed the turn, provided this has taken place within a defined time of the instruction being issued, the *planned trajectory* **should** be remodelled from the actual aircraft position, and adjusting the next turn point and/or the route rejoining fix accordingly.
- 3.5.1.7 For an aircraft on an assigned heading, the *planned trajectory* **should** be remodelled according to the actual track of the aircraft if within a defined limit of the calculated track, and adjusting the next turn point and/or the route rejoining fix accordingly.

3.6. System supported coordination

The system supported coordination defines the coordination tools and facilities for Multi-Sector Planner roles.

- 3.6.1 The *planned trajectory* **shall** be updated using data of notification process, pre-departure co-ordination, inter-sector coordination and co-ordination process with adjacent ATSUs.
- 3.6.2 In case of multi-sector planner, the system **shall** permit the inter-sector co-ordination between MSPs and inter-centre co-ordination between MSP and adjacent ATS unit.
- 3.6.3 Within the airspace volume assigned to MSP, the inter-sector co-ordination **shall** be inhibited except when initiated manually between the concerned Tactical Controllers within the MSP jurisdiction.

3.7. The Tactical Trajectory

The tactical trajectory projects the current clearance from the aircraft position over the tactical trajectory prediction horizon.

- 3.7.1.1 The *tactical trajectory* **shall** extend from the present position of the flight.
- 3.7.1.2 Where a flight is cleared on a *route*, the *tactical trajectory* **shall** follow the sequence of points defined by the *route* to the extent of the prediction horizon.
- 3.7.1.3 For a flight on an assigned heading, the *tactical trajectory* **shall** project the corresponding ground track over the tactical trajectory prediction horizon.
- 3.7.1.4 For a flight cleared direct to a point off the planned *route*, the *tactical trajectory* **shall** extend to the point and then continue the ground track as necessary to the extent of the tactical trajectory prediction horizon.
- 3.7.1.5 Where a heading or direct clearance is entered for application after reaching a designated waypoint but still within the prediction horizon of the *tactical trajectory*, the *tactical trajectory* **shall** extend to the designated waypoint, before incorporating the designated heading or direct clearance.
- 3.7.1.6 For flights for which a lateral deviation is detected (see *MONA-SPEC*) a *tactical deviation trajectory* **may** be created according to an extrapolation of the track state vector.
- 3.7.1.7 The *tactical trajectory* **shall** climb or descend from the current aircraft level to the *CFL*, and thereafter maintain the *CFL* as necessary to the extent of the tactical trajectory prediction horizon.
- 3.7.1.8 The *tactical trajectory* **shall** comply with level restrictions included in the description of a *SID* assigned to the flight or issued as part of the departure clearance unless a *CFL* has been entered.

4 TRAJECTORY ACCURACY REQUIREMENTS

4.1. Basic Metric – Longitudinal Error

4.1.1 Input Metrics

Meteorological Conditions⁹	Peak
Wind Vector Error	7 Knots
Temperature Error	2 °C
Track State Vector¹⁰	
Position Error When in Uniform Motion	120 m
Along-track Speed Error When in Uniform Motion (m/s)	1.5 m/sec

4.1.2 Output Metrics

4.1.2.1 The system should achieve the following longitudinal accuracy:

Longitudinal Position Prediction Error - NM per minute of prediction	Magnitude of Mean	Standard Deviation
Cruise Phase (FL 200 – FL 300)	0.1 NM/min	0.2 NM/min
Cruise Phase (FL 300 – FL 600)	0.1 NM/min	0.2 NM/Min
Climb Phase (FL 200 – FL 300)	0.2 NM/min	0.6 NM/Min
Climb Phase (FL 300 – FL 600)	0.2 NM/min	0.4 NM/Min
Descent Phase (FL 200 – FL 300)	0.2 NM/min	0.6 NM/Min
Descent Phase (FL 300 – FL 600)	0.2 NM/min	0.6 NM/Min

4.2. Basic Metric – Vertical Error

4.2.1 Input Metrics

	Peak
Meteorological Conditions	
Wind Vector Error	7 Knots
Temperature Error	2 °C
Track State Vector	
Position Error When in Uniform Motion	120 m
Along-track Speed Error When in Uniform Motion (m/s)	1.5 m/sec

⁹ Peak meteorological errors have been chosen such that they encompass achievable forecast values as documented in the EATMP - Met Data in ATM – Final Report [MET-ATM].

¹⁰ Values taken from the Radar Surveillance Standard for Enroute and Major Terminal Areas [SUR-STD], Table 7A – Accuracy requirements enroute assuming dual SSR coverage.

4.2.2 Output Metrics

4.2.2.1 The system should achieve the following vertical accuracy:

Vertical Position Prediction Error – feet per minute of prediction	Magnitude of Mean	Standard Deviation
Climb Phase (FL 200 – FL 300)	100 ft/min	300 ft/min
Climb Phase (FL 300 – FL 600)	100 ft/min	200 ft/min
Descent Phase (FL 200 – FL 300)	100 ft/min	300 ft/min
Descent Phase (FL 300 – FL 600)	100 ft/min	200 ft/min

4.3. Basic Metric – Lateral Error

4.3.1 Input Metrics

	Peak
Meteorological Conditions	
Wind Vector Error	7 Knots
Temperature Error	2 °C
Track State Vector	
Position Error When in Uniform Motion	120 m
Along-track Speed Error When in Uniform Motion (m/s)	1.5 m/sec

4.3.2 Output Metrics

4.3.2.1 The system should achieve the following lateral accuracy:

Lateral Position Prediction Error - NM per minute of prediction	Magnitude of Mean	Standard Deviation
	0.1 NM/min	0.3 NM/min

ANNEX A: GUIDELINES FOR THE USE OF THE EUROCONTROL SPECIFICATION FOR TRAJECTORY PREDICTION

1 INTRODUCTION

These guidelines accompany the Trajectory Prediction specification in order to give advice to ANSPs in the use of the specification for a local system procurement, and to ensure a correct understanding of the specification.

The principal means by which these guidelines are provided is through satisfaction arguments that are presented for each operational objective (identified by blue italicized text in the functional requirement sections of the specification). For the purpose of this specification, a satisfaction argument provides domain knowledge and assumptions that, when combined with the specification of the required behaviour of the system, demonstrate that the operational objective will be achieved. Assumptions may be about elements external to the ANSP (e.g. aircraft performance) and elements internal to the ANSP, which can be considered as requirements on the ANSP's operation of the system. Collectively, the domain knowledge and assumptions should allow a complete understanding of the specification, and should permit the ANSP to decide the applicability of the requirements to their own environment.

In the electronic version of this document, certain figures can be animated by clicking on them. Figures for which an animation is available are identified by the cursor taking the form of a hand and the text "Click to animate" appearing when the cursor is placed over the figure.

2 FUNCTIONAL REQUIREMENTS

2.1. Flight Intent (3.1)

The initial source of flight intent is the filed flight plan and amendments. Items of the filed flight plan that might affect the *flight script* are the callsign, aircraft type, aerodromes of departure and destination, estimated times, flight rules, type and category (GAT/OAT), equipment fit and status, requested cruising level and speed and *route*.

The Area of Responsibility (AoR) is an airspace of defined dimensions within which an ATSU provides air traffic services.

The Area of Interest (AoI) is a defined volume of airspace not constrained by the AoR within which the flight trajectories are required for any given function to meet the needs of an ATSU.

Many sub-functions require data related to aspects of the *trajectory* outside the *AoR*, e.g. to identify a destination airport outside the *AoR* for which a flight commences its descent within the *AoR* in order to calculate the Top of Descent (*TOD*). Whilst it is over-simplistic to assume that this area is the same for all such sub-functions, in general it is referred to in this document as the *AoI* and represents the set of data required for the performance of any given sub-function to meet the needs of the *ATSU(s)* concerned.

The portion of the *route* through the *Area of Interest* is identified in the route field of the flight plan and decomposed to a sequence of points. For flights that re-enter the *AoR*, each passage through the *AoR* is identified. Checks are performed to ensure the validity of the entered *route* information.

2.1.1 Sources of Flight Intent (3.1.1)

The system determines the flight intent from a filed flight plan and subsequent amendments.

Domain Knowledge

The aircraft operator files a flight plan containing information on the flight intent.

Before departure, the aircraft operator files any changes to the flight intent in an amendment to the flight plan.

Once airborne, the aircrew pass any further changes of intent via R/T or CPDLC to the controller.

The aerodromes of departure and destination, together with the route, describe planned the horizontal path of the aircraft. The requested cruising speed[s] and requested cruising level[s] describe the intent in the longitudinal and vertical dimensions respectively. The flight rules govern the validity of the intended route and profile. The aircraft type is used in the validation of the flight intent and in the estimation of the trajectory.

Published route elements (routes, waypoints, SIDs, STARs, etc.) might be changed at a new Aeronautical Information Regulation and Control (AIRAC) cycle. In the day leading up to the new AIRAC publication date, the system might store flight plans operating both before and after the AIRAC date. In these cases, the date of flight is used to determinate the validity an definition of the aeronautical data.

Assumptions

In the case DCT/FRA environment data will need to be known within the whole DCT/FRA such that controllers are able to enter clearances to the exit of the DCT/FRA airspace.

The flight plan and amendments are received by the system, either from the IFPS or directly from the aircraft operator, and are submitted to the trajectory prediction.

The controllers and flight data assistants have a means to enter flight intent and amendments into the system and these are submitted to the trajectory prediction.

2.1.2 Route Extraction (3.1.2)

The system determines the planned horizontal path through the Area of Interest.

Domain Knowledge

Route normally expressed by means of published routes covering portion from where aircraft joins route network after departure to where it leaves before arrival. Arrival and departure routes dependent on runway in use and therefore normally assigned later by ATC. However, if included in the plan they may be inserted.

Significant points normally inserted at junctions between routes and to express new speeds/levels/rules and for boundary points. Significant point names not unique. Also routes span many FIRs. Therefore, simple recognition of an element name by matching to a knowledge base of local names not sufficient to recognize local portion. Additional checks might be necessary, such as checking that the point and route are consistent.

Route may be interrupted where flight changes to VFR.

Where allowed by operational procedures, routes off the route network may be filed by means of a sequence of published waypoints or as coordinates (expressed at lat/long). Aircraft flies direct (great circle) between points.

ANSP requires just the path through its Aol. If departing from within the Aol, departure aerodrome is first point; otherwise it is the first recognized point on the route. Similarly for arrival/exit.

Recognizing that a portion of the filed route is within the Aol is achieved by recognition of a point name, or the junction between two recognized routes. Then go back to find first point within Aol.

A flight might leave the Aol and then re-enter, either due to the shape of the Aol or because the flight is of an out-and-back type (e.g. practice touch-and-go).

Assumptions

System contains a database of all published points and routes (ATS routes and SIDs/STARs) that may be used by aircraft operators to describe their planned route through the Aol.

For each route in the database, the system stores the sequence of published significant points (navigation aids and reporting points).

2.1.3 Speed and Level Extraction (3.1.3)

The system determines the planned speed and level profile within the Aol.

Domain Knowledge

The flight plan contains an initial cruising speed and level. Changes to the initial speed and level at points along the route can be planned. A clearance to change level must be given by ATC prior to the aircraft leaving its previously cleared level.

2.1.4 Intent Consistency (3.1.4)

The system ensures that the flight intent is consistent with the airspace and aircraft type.

Domain Knowledge

The IFPS performs an initial check of the consistency of the flight plan for GAT IFR flights. Additional checks are required against the local view of the environment.

Support staff at the ACC/APP are able to correct erroneous flight plans.

Assumptions

A work position is configured where erroneous flight plans and amendments are queued for manual action.

2.2. ATC Procedures and Strategic Constraints (3.2)

2.2.1 Departures (3.2.1)

A SID or preferential departure route is assigned to a flight, where applicable, before departure.

Domain Knowledge

A SID is a procedure that describes how an aircraft proceeds from take-off to the en-route network. Therefore, the runway identity and route identity are the two primary criteria in the assignment of a SID to a flight.

A SID might also have an activation schedule defining its availability (e.g. for noise abatement reasons).

A SID might be defined for use only by certain defined aircraft categories (e.g. twin-jet, etc) or aircraft types for noise abatement or aircraft performance reasons.

Irrespective of the presence of an activation schedule, a SID might be unavailable for use (e.g. due to equipment unavailability).

As a SID is defined for use with a particular runway, it is normally assigned by ATC according to the runway in use.

In the occasions when a *SID* is included in the filed flight plan this can only be used by the flight if it is consistent with the *route* and departure runway.

The controller may manually assign a *SID* to a flight, but only one that is compatible with the departure runway to be used by the flight.

Assumptions

The system contains a database of SIDs, identifying the selection criteria, and specifying the horizontal path and any speed or level constraints.

A work position exists where flight plans that require manual intervention due to the filed SID being invalid for the flight or for which no SID meets the validity criteria, are queued.

Assignment of departure runway might be by manual entry or via a Departure Manager.

2.2.2 Arrivals (3.2.2)

A STAR or preferential arrival route is assigned to a flight, where applicable, prior to commencing its approach.

Domain Knowledge

An instrument approach procedure might be defined from the *IAF* to the runway threshold.

A Standard Terminal Arrival Route (*STAR*) provides the transition from the enroute structure to an outer fix or instrument approach fix/arrival waypoint in the terminal area. The primary criteria for the assignment of a *STAR* to a flight are the route and the runway.

A *STAR* might also have an activation schedule defining its availability (e.g. for noise abatement reasons).

A *STAR* might be defined for use only by certain defined aircraft categories (e.g. twin-jet, etc) or aircraft types for noise abatement or aircraft performance reasons.

A *STAR* might be defined for use only by certain defined aircraft operators where special procedures with these operators have been agreed.

Unless filed or manually inserted as described above, a *STAR* is selected automatically by the system on the basis of the runway expected to be used by the flight, *route*, category of aircraft, estimated landing time, aircraft operator and *STAR* availability status.

Irrespective of the presence of an activation schedule, a *STAR* might be unavailable for use (e.g. due to equipment unavailability).

The *STAR* is normally assigned to a flight by ATC according to the arrival runway and route.

In the occasions when a *STAR* is included in the filed flight plan this can only be used by the flight if it is consistent with the *route* and arrival runway.

Assumptions

The system contains a database of *STARs*, identifying the selection criteria, and specifying the horizontal path and any speed or level constraints.

For each *STAR*, the system also contains the description of the path from the *STAR* end point to the runway or assumes a direct path (which may be defined as an instrument approach procedure).

A work position exists where flight plans that require manual intervention due to the filed *STAR* being invalid for the flight or for which no *STAR* meets the validity criteria, are queued.

Assignment of arrival runway can be by manual entry or via an Arrival Manager.

2.2.3 Strategic Constraints (3.2.3)

The system applies strategic constraints corresponding to normal ATC procedures.

Domain Knowledge

Procedures are often defined by ATC to reduce the tactical workload, e.g. by separating traffic flows, or avoiding certain traffic flows from penetrating a sector. These procedures are modelled by the system with the use of *strategic constraints*. If workload permits, the standard procedure may be overridden by tactical clearances to allow a flight a more optimum trajectory.

Examples of *strategic constraints* include the following:

- Agreed boundary crossing levels defined in the *LoA* between *ATS* units, either globally or based on flight characteristics such as the departure aerodrome or the boundary crossing points;
- Level constraints applicable to flights on departure routes including those resulting from *ATC* procedures;

- Speed limits within a *TMA*;
- Crossing an area within a specified level band due to the presence of an active *TSA*; the trajectories of flights that would climb or descend through the band must pass above or below it;
- A maximum *enroute cruising level* applicable to flights between two specified airports;
- Permitted enroute cruising levels applicable to flights on a designated route/direction.

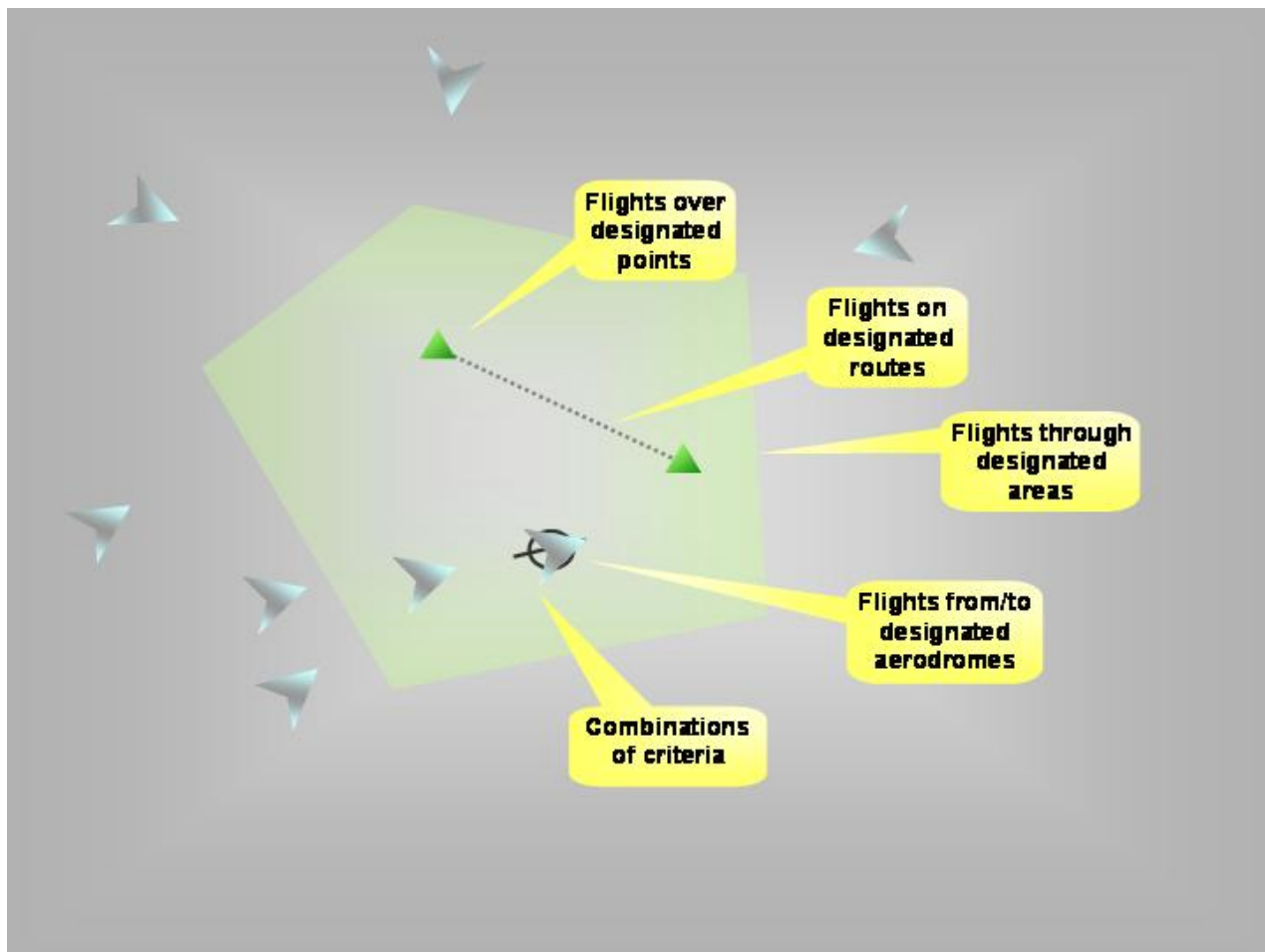


FIGURE 3 – STRATEGIC CONSTRAINTS ACQUISITION

The application of a strategic constraint results in one or both of the following:

- The crossing of a point, line or area:
 - ⇒ at a specified level;
 - ⇒ at or below a specified level;
 - ⇒ at or above a specified level;
 - ⇒ between specified levels.
- A speed to be maintained during a specified procedure or in a defined airspace.

The definition of a constraint by application on crossing a defined line allows the constraint to be maintained in case that the flight is given a heading or direct routing that passes abeam the original constraint point.

On occasions, a strategic constraint may require the aircraft to operate outside of its nominal performance envelope (e.g. where a minimum level must be reached in order to clear an obstacle or segregated airspace).

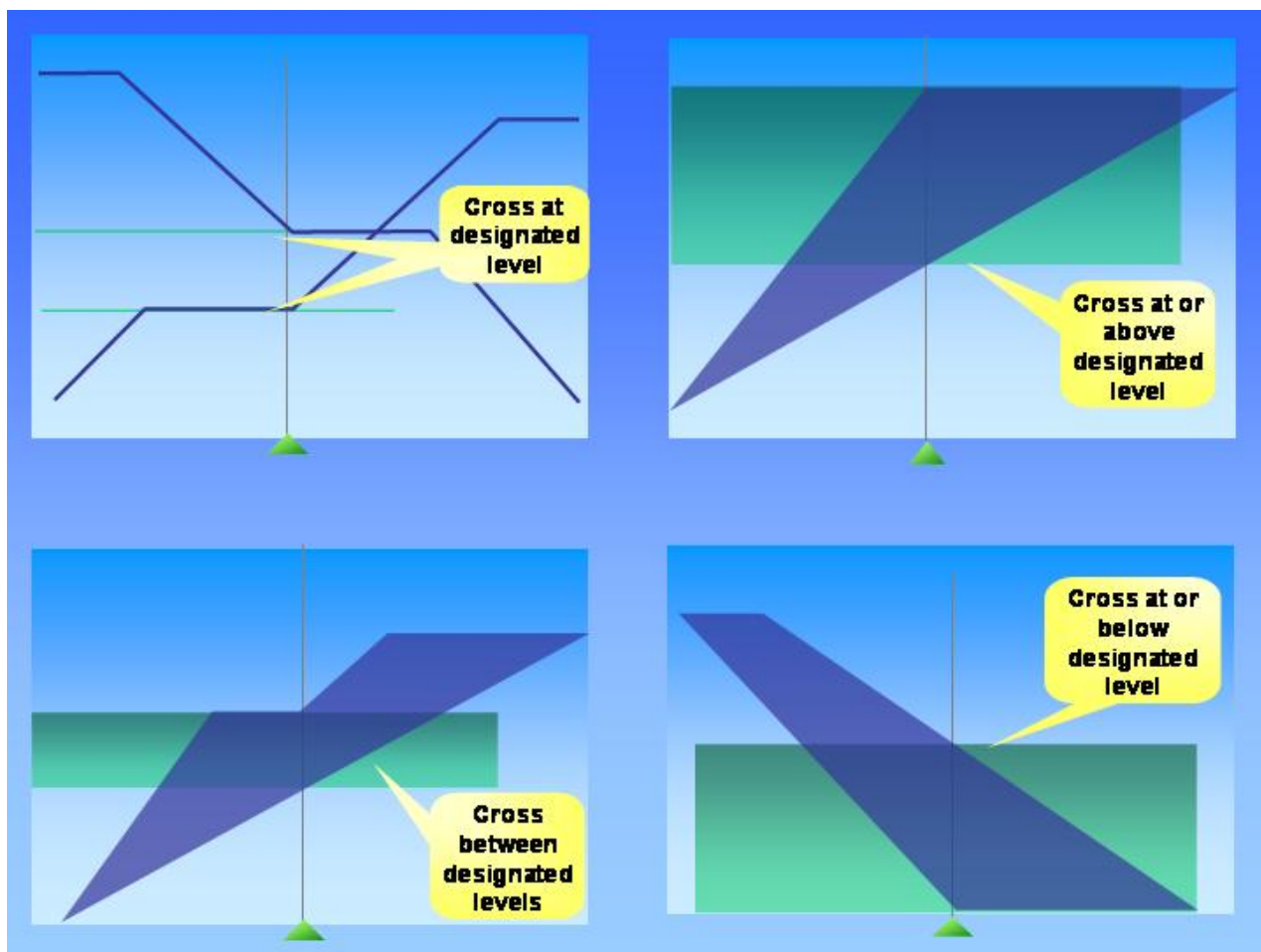


FIGURE 4 – STRATEGIC CONSTRAINT SCOPE

Level restrictions included in the description of a *SID* or issued as part of the departure clearance are considered as *CFLs*. If the *planned trajectory* is required to respect such level restrictions, they must be declared as *strategic constraints*.

Dynamic constraint management supports the process of Demand and Capacity Balancing by allowing to apply measures such as level-capping on traffic flows to avoid sector overload.

Assumptions

The system contains a database of constraints. Each constraint defines at least one of the following reference criteria by which it is selected for application to a flight:

- departure aerodrome,
- destination aerodrome,
- significant point,
- ATS route,
- designated area.

The constraint also identifies a constraint reference point or line at which the constraint is to be achieved.

For each constraint, a number of restrictions are defined, each identifying the *enroute cruising levels* to which it applies. Each restriction defines the speed and or level limitations to be applied.

Thus, the following example constraints could be defined:

Constraint 1: “All departures from EZXX to EXZZ must cross point ZZZ at FL140 or below.”

Reference Criteria: Departure Aerodrome: EZXX, Destination Aerodrome: EXZZ

Reference Point: ZZZ

Restriction 1: ECL 000 to 600
Limitation: FL 140 or below

Constraint 2: “Departures from EZXX routing via YYY must cross point ZZZ at FL140 or below if their ECL is below FL300.”

Reference Criteria: Departure Aerodrome: EZXX, Significant Point: YYY

Reference Point: ZZZ

Restriction 1: ECL 000 to 300
Limitation: FL 140 or below

The system supports dynamic update of strategic constraints as necessary to support Demand and Capacity Balancing.

2.2.4 Conditional Routes (3.2.4)

The system ensures that any planned traversal of a closed conditional route is notified to the controller.

Domain Knowledge

Conditional Routes (CDR) are classified into three types:

- Category 1 – Permanently Plannable

Cat 1 *CDRs* are defined in the *AIP* of the State concerned together with the times of opening and closure. Air operators can file Cat 1 *CDRs* in flight plans, including *RPLs*.

- Category 2 – Non Permanently Plannable

Cat 2 *CDRs* are subject to opening and closing on a much shorter time scale than Cat 1 *CDRs* and thus cannot be filed in *RPLs*; they can however be used in *FPLs*. Cat 2 *CDR* availability is notified to aircraft operators (*Aos*) by the use of the Conditional Route Availability Message (*CRAM*) sent from the *CFMU*. If processed correctly by the *Aos* there should be comparatively few occasions when an aircraft is filed on a closed Cat 2 *CDR*.

- Category 3 – Not Plannable

Cat 3 *CDRs* are published but available on *ATC* instructions only. They are not permitted to be filed and therefore trajectory prediction should not encounter a filed *route* using a Cat 3 *CDR*.

The availability of a conditional route is defined with reference to levels; a closed *CDR* might be avoided either by the aircraft changing level or route.

Assumptions

The system contains a database of category 1 & 2 conditional routes, defined by its identity and waypoints. Each category 1 & 2 conditional route contains an activation schedule (timetable) and activation level limits. An alternative route might be associated with a conditional route, which can be assigned to a flight planned on the conditional route if an alternative level is not available.

The warnings of *CDR/TSA* crossing are presented according to operational procedures and the overall alerting principles adopted by the ANSP.

The system identifies category 3 CDRs that are available to shorten a planned route.

Domain Knowledge

Category 3 CDRs become available on an ad hoc basis when airspace that they traverse is released by the military. Flights that have been planned on routes that circumnavigate the restricted airspace can then be cleared by ATC on the CDR, thus shortening their routes.

In cases where CDR is automatically assigned to a flight, the controller responsible for passing the clearance to the aircraft needs to be notified.

Assumptions

The system contains a database of category 3 conditional routes defined by its identity and waypoints. Each category 3 conditional route contains references to portions of ATS routes that it can replace.

2.2.5 Area Crossing Restrictions (3.2.5)

The system ensures that direct route segments that traverse active TSAs or TRAs are referred for manual action

Domain Knowledge

Within the concept of the Flexible Use of Airspace (FUA), Temporary Reserved Areas (TRAs) and Temporary Segregated Areas (TSAs) are established in response to the need for civil, military, R&D, training, test flights or activities of a temporary nature which, due to the nature of their activities, need segregation to protect both them and non-participating traffic.

TRAs and TSAs are allocated by the Airspace Management Cell pre-tactically (normally the day before operations) in response to daily requests for specific periods, and are activated tactically in accordance with the actual requirement. TRAs and TSAs may be defined as Variable Profile Areas (VPA) in which the geographic scope is defined by reference to one or more published airspace blocks.

By definition, a GAT flight across an active TSA is not permitted and therefore, where such a traversal is planned, the flight plan is referred for manual correction. GAT flights that are planned to cross an active TRA are also referred for manual action, though in this case a clearance might be granted to cross the TRA after coordination with the designated military authority.

If an avoiding route is required, controller can request the calculation of an avoiding *route* by the system, whereupon a defined alternative *route* is inserted, if available; otherwise, where a choice exists, the shortest *route* around the *TSA* is identified. It might be possible in some instances to use or join *ATS* routes that circumnavigate the *TSA*, provided that the rules for selection of the *route* are specified. If the proposed option were not acceptable for the controller, the option for manual specification of the *route* would always exist, subject to the availability of a suitable *HMI*.

Assumptions

The system contains a database of TRAs and TSAs, defining their extent, timetable, and actual activation status.

In the case of TRAs or TSAs being described by means of a VPA, the system contains a database defining the elementary airspace blocks from which the VPA is composed.

For each TSA/TRA, the system contains a database of avoiding routes, each defined by a series of waypoints.

The warnings of CDR/TSA crossing are presented according to operational procedures and the overall alerting principles adopted by the ANSP.

The system determines penetrations of PCAs and RCAs necessary to support the civil/military coordination process.

Domain Knowledge

The FUA concept defines *Prior Coordination Airspace* (PCA) for airspace within which military activities can take place on an ad-hoc basis with individual GAT transit allowed under rules specified in the LoAs between the units concerned. When OAT traffic is of low intensity, the need for civil/military co-ordination of off-route GAT unnecessarily increases controller workload and therefore *Reduced Coordination Airspace* (RCA) is defined. The RCA procedure is usually applied for a very large area such as the entire FIR/UIR, but also for critical ACC sectors which have different capacity figures according to the existence of military activity or not.

The system identifies trajectories that traverse RCAs and PCAs in order to perform the necessary system-supported coordination with the military unit.

Assumptions

The system contains a database of PCAs and RCAs, defining their extent and coordination requirements.

2.2.6 Sector Computation(3.2.6)

The system determines sector penetrations and coordination points necessary to support the sector control sequence.

Domain Knowledge

Control teams operate in sectors, each defined by a volume of airspace and radio frequency. Prior to an aircraft entering a sector, the conditions of entry have to be coordinated with the preceding sector controllers. Coordination is often performed with reference to a waypoint close to the boundary between the sectors or reference to published point (range and bearing) or unpublished point expressed in LAT/LONG.

The system determines the list of sectors penetrated by the flight trajectory and their respective coordination points in order to distribute the flight data to the appropriate sectors and to provide system-supported coordination.

Depending on the role of the ACC, in addition to the sectors provided for GAT, there might be an independent set of sectors for OAT that overlays the GAT sectors. In this case, OAT flights, or portions of flights, are assigned to the OAT sectors.

Flight information for GAT might be notified to ATS units responsible for OAT, and similarly information on OAT might be notified to ATS units responsible for GAT.

A list of sectors in close proximity with the route of the flight might also be determined to allow sectors in close proximity to the route to be notified of flights that may stray into their airspace (either unintentionally or due to a tactical diversion to avoid weather).

In complex areas (typically large TMAs) a volumetric approach is not enough to correctly determine the sector sequence. In these cases, the departure or destination aerodrome is used to determine the actual sector to control the flight.

Assumptions

The system contains a database of sectors, defining for each the volume of airspace comprising the sector.

The system contains a database of coordination points between sectors, though not necessarily located on the boundary between the sectors.

2.3. Tactical Constraints Application (3.3)

Tactical constraints refer to coordination and clearance instructions on individual flights entered by the planner (normally limited to coordination instructions) and executive controllers, often superseding *strategic constraints*.

A tactical constraint is an instruction that is issued to a flight or known in advance of such issue for the purpose of tactical control.

Tactical constraints include the following:

- Heading or track
- Proceed to point (Direct)
- Resume normal navigation
- *Cleared Flight Level (CFL)*
- Speed
- Time at position (delay absorption)
- Vertical Rate of Change (VRC)
- Exit/entry level (*XFL/PEL*)
- Hold and hold cancellation (including *orbit*)
- Offset and end offset
- Missed Approach
- *Route* amendment

A constraint is considered as closed if, when applied to a flight, a continuous trajectory is maintained throughout the Aol.

To route direct from present position to a specified point on the *planned trajectory* or to apply a rate of climb until passing a specified level are examples of *closed constraints*.

A constraint is considered as open if, when applied in isolation to a flight, a continuous trajectory through the Aol can not be deduced; another instruction is needed to know the way the flight will resume its normal navigation.

A heading instruction is an *open constraint* and is completed by an instruction to resume navigation or to proceed direct to a specified point.

Open constraints comprise the following :

- heading or track where the intended limit of the constraint is not known;
- *indefinite hold* (including *orbiting*) where the time at which the flight is to leave the holding pattern is not known;
- *CFL* in climb or descent phases;
- speed restriction in climb or descent phases;
- vertical rate instruction.

The *planned trajectory*, as a representation of the probable flight behaviour over the complete *Aol*, normally incorporates only the *closed tactical constraints*. However, in certain cases assumptions can be made on probable behaviour subsequent to an *open constraint*, thereby allowing the constraint to be closed and therefore applied to the *planned trajectory* (e.g. the application of a vertical rate might be assumed to be terminated on reaching the *CFL*).

2.3.1 Sector Entry/Exit Conditions (3.3.1)

When coordination is between horizontally-adjacent sectors, an entered entry/exit level is applied as a constraint on the entry/exit coordination point and the trajectory recalculated.

Domain Knowledge

Depending on the LoAs or operational procedures, a flight in the climb or descent phase might not need to be established at the coordinated level at the point of transfer, but might be climbing or descending towards the coordinated level. If the permitted level band is not specified by the LoA or standard procedure, then this may be included as supplementary data in the coordination. (e.g. "Climbing to 320, crossing at or above 240").

In the figures below, it is assumed that no supplementary flight level is given, and therefore the trajectory is modelled to reach the XFL by the coordination point.

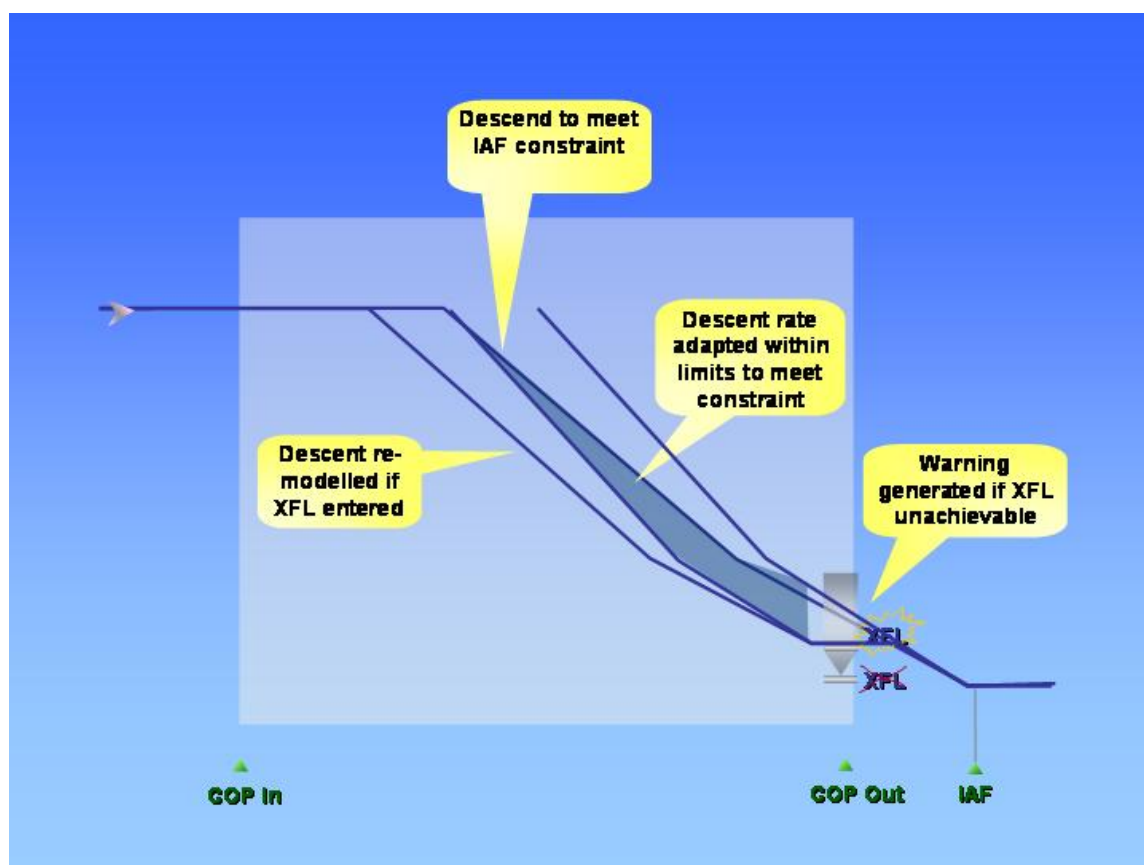


FIGURE 5 – SECTOR ENTRY/EXIT LEVEL IN DESCENT

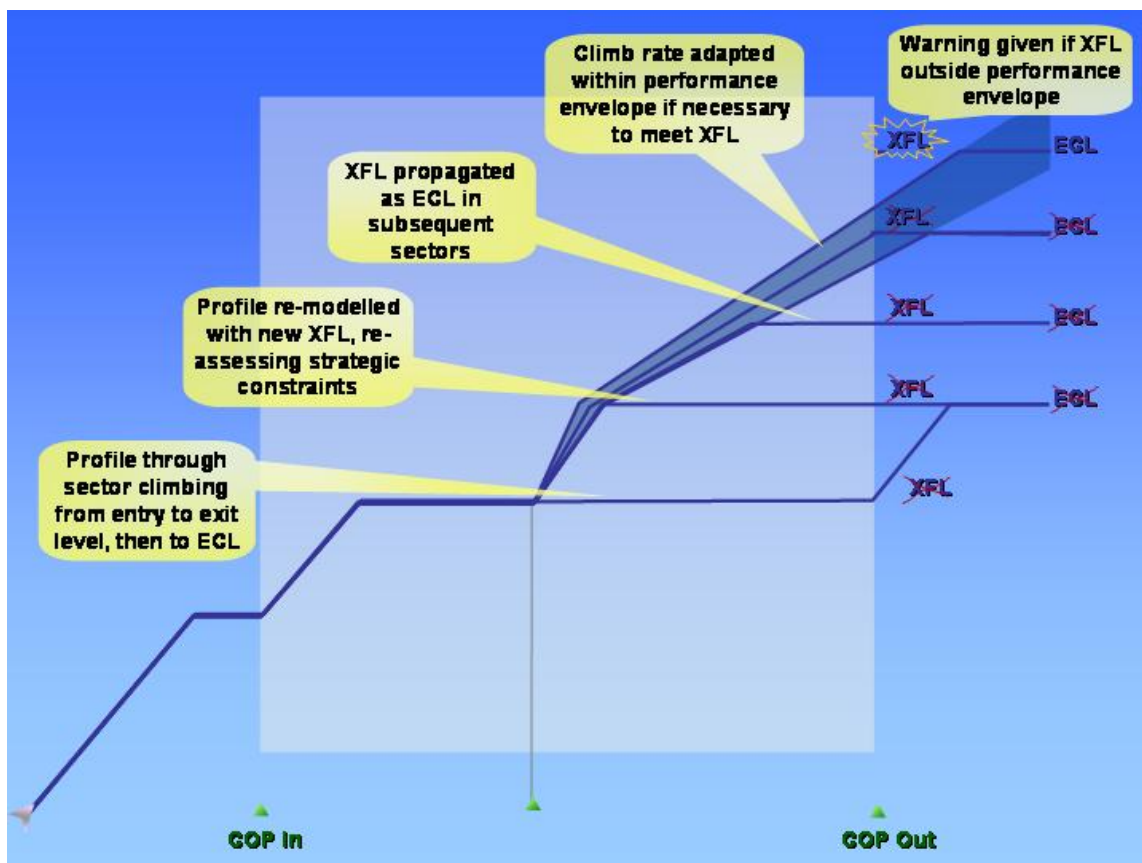


FIGURE 6 – SECTOR ENTRY/EXIT LEVEL IN CLIMB

For layered sectors, a common procedure is to coordinate climbing traffic to the highest level within the lower sector, and descending traffic to the lowest level in the upper sector. The aircraft are transferred shortly before reaching the coordinated level and, if traffic permits, are normally cleared to continue their climb/descent. Therefore, in these cases, the coordinated level has no effect on the trajectory.

On occasions, a climbing flight might not be able to continue its climb to the sector above, and would need to be coordinated with the sector horizontally adjacent. In this case, the trajectory is amended such that the climb is restricted and the aircraft enters the adjacent sector. A potential ambiguity exists if the aircraft were coordinated at the highest level of the sector, as this could be used to transfer the flight to either the sector above or the sector horizontally adjacent. Therefore, the controller needs to state explicitly the sector to which the aircraft will be transferred.

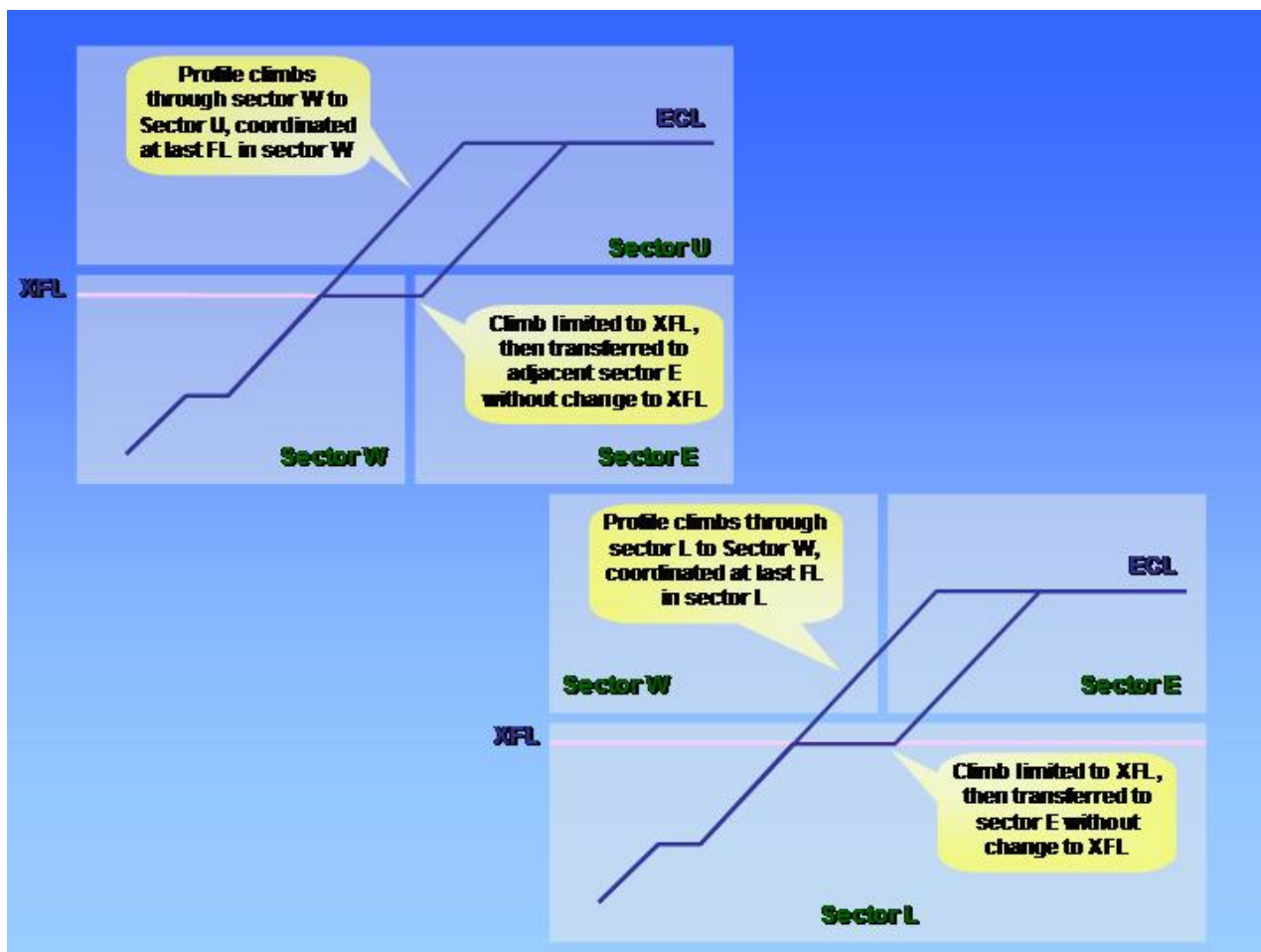


FIGURE 7 – NEXT SECTOR DESIGNATION

Assumptions

The coordinated *entry/exit level* is entered into the system either from OLDI messages (AoR boundaries) or from controller input.

By applying the coordinated *entry/exit level* as a constraint (target level) on the boundary point between the *sectors*, rather than as an absolute level that the flight will cross the boundary, the expected performance of the aircraft can be taken into account in the modelling of the profile.

In the special case where a *trajectory* was traversing a boundary between an upper and lower *sector*, but the entered level is in the vertical span of the transferring *sector*, it is assumed that the aircraft will no longer be passed between the upper and lower *sectors*, but will pass to the horizontally-adjacent *sector*. In this case the boundary point is moved accordingly and the flight level applied to the new coordination point.

2.3.2 Enroute Cruising Level (ECL) (3.3.2)

Upon entry of a new ECL, the trajectory is modelled climbing or descending at the specified point if entered, otherwise from the current aircraft position, to the new ECL.

Domain Knowledge

The *ECL* is a notional level that, in the absence of constraints, equates to the *RFL*. In the case where a flight is not permitted to cruise at its *RFL* for any or a part of its route, due to the presence of a *strategic constraint* (level limit) which applies to flights between the aerodromes of departure and destination, the *ECL* will be limited to the level defined by the constraint. The *ECL* may also be changed by instruction from ATC where the flight is to maintain a different cruising level, typically due to the proximity of a flight at the *RFL* on the same *route*.

As with the *RFL*, the *ECL* can be changed for different *segments* of the *route* and, if different in the cruise phase, is changed to the *XFL* on passing the *sector* boundary. The notion of *ECL* ceases to exist after the final *TOD* from cruising level.

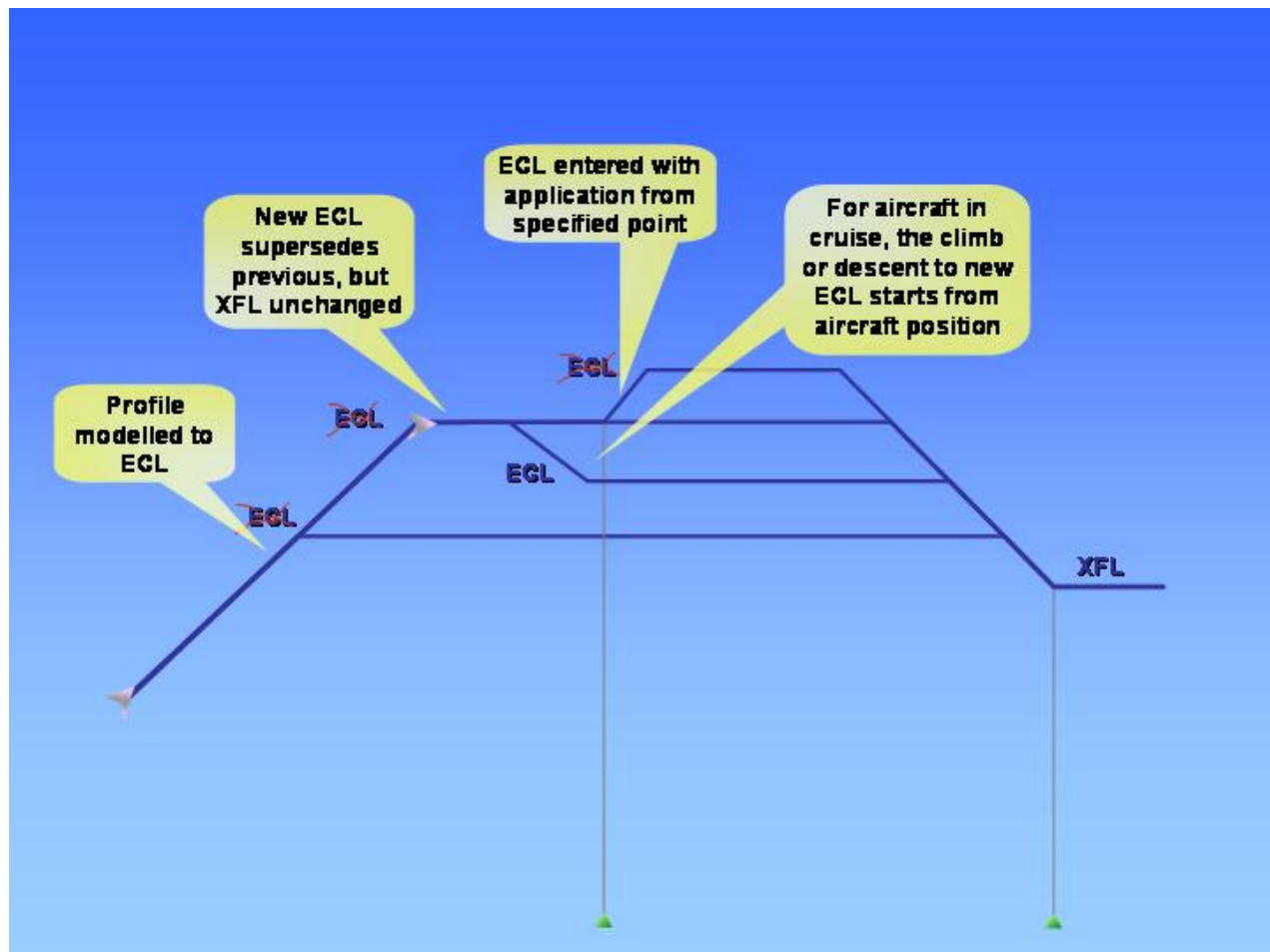


FIGURE 8 – ENROUTE CRUISING LEVEL

Assumptions

The system might allow explicit entry of the *ECL* by the controller and/or derive the *ECL* from entered *XFL* or *CFL*.

When an *ECL* is entered, the flight is processed using the *ECL* and, if the flight has not reached *TOC*, it is recalculated accordingly, but the *RFL* remains available for display in case the level becomes available later in the flight. The *ECL* remains applicable until *TOD* but can be changed. The entry of a new *ECL* after *TOC* results in a vertical transition to the new level from the present position unless the point at which the change is to take place is specified.

2.3.3 Cleared Flight Level (CFL) (3.3.3)

If, during the climb or descent phases, a flight is cleared beyond the level of the currently applicable strategic constraint, the constraint is bypassed, the climb/descent continuing to the next constraint.

Domain Knowledge

The *CFL* is considered an *open constraint* as the duration of the level-off at the *CFL* is not known; it is therefore not normally applied directly to the *planned trajectory*. However, if a climbing flight approaches within a vertical parameter distance of its *CFL* (i.e. without a subsequent *CFL* being issued) then the *trajectory* may be levelled out for a parameter distance or time which should be of comparatively short duration (see 3.5).

The *CFL* might be applied indirectly to the *planned trajectory* by overriding *strategic constraints* if these can be considered superseded by the *CFL*. If the *CFL* is within the limits of a *strategic constraint* that is currently applicable to the flight, the flight is considered to be complying with its *planned trajectory* and no modification need be made to the *trajectory*. A typical application is a flight cleared to a standard level in accordance with normal *ATC* procedures. However, if the *CFL* of a climbing flight is above the level of any current or subsequent *strategic level constraint*, the *strategic level constraint* is considered superseded.

When a new *CFL* is entered for a flight already in the cruise phase, this might be considered a new *Enroute Cruising Level* (ECL).

According to operational procedures, additional tactical constraints corresponding to clearances such as “descend now” or “descend now and be level by [fix]” might be considered.

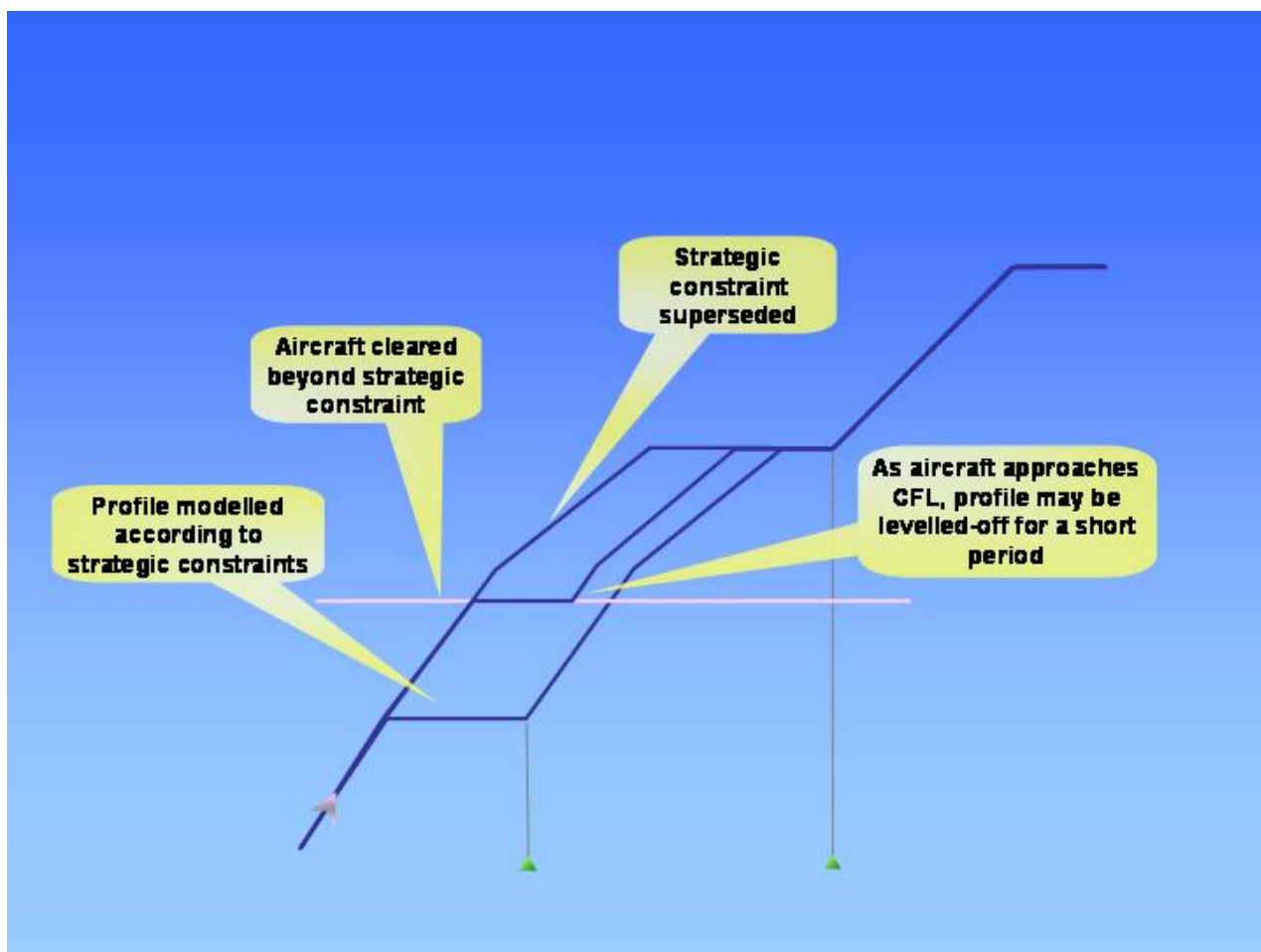


FIGURE 9 – CLEARED LEVEL IN CLIMB

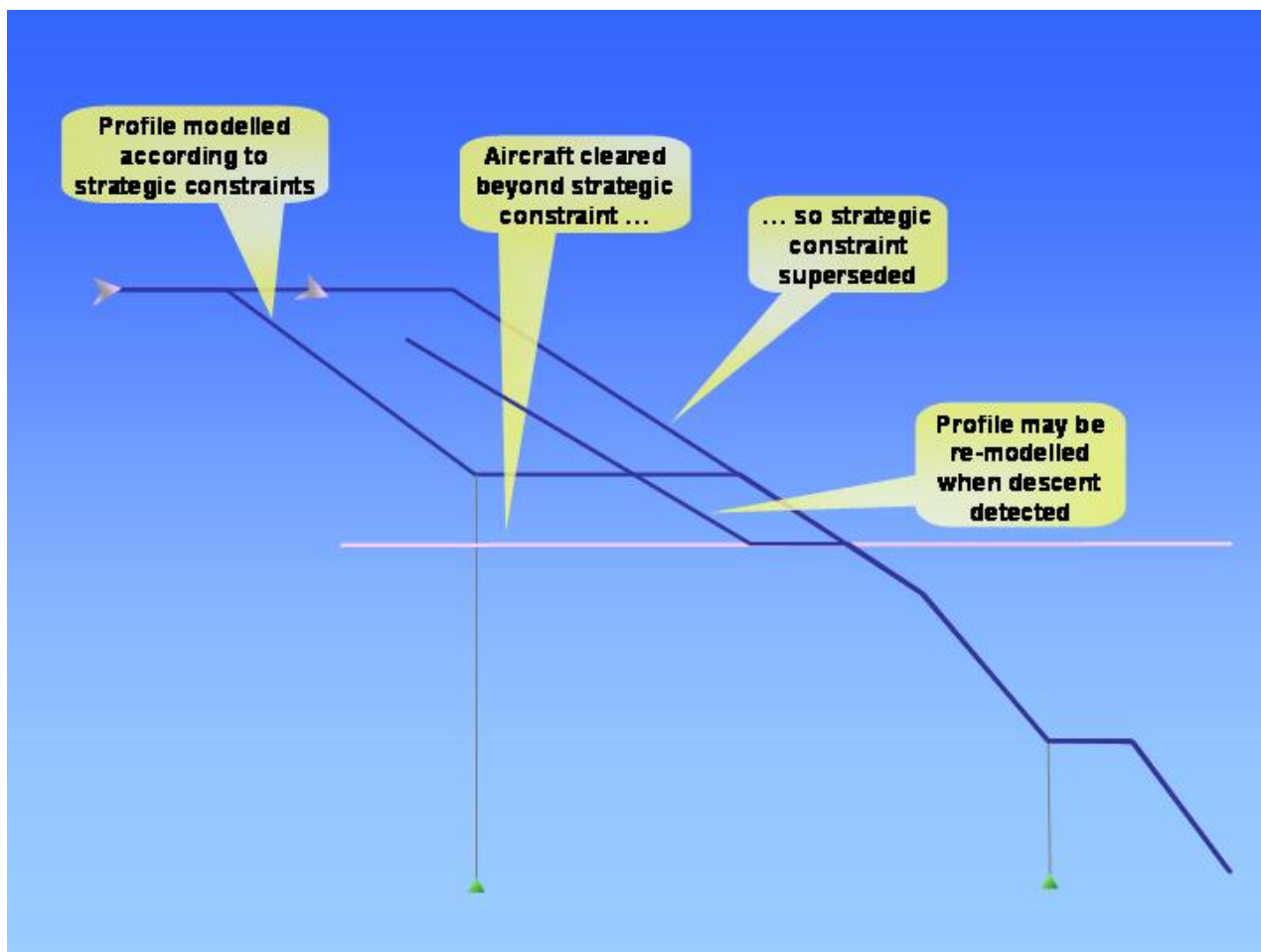


FIGURE 10 – CLEARED LEVEL IN DESCENT

Assumptions

The system allows entry of *CFL* from controller input.

2.3.4 Vertical Rate of Change (VRC) (3.3.4)

An entered expedite, minimum or maximum VRC is applied to the trajectory from the current level of the aircraft to the CFL if the currently applied VRC is outside the specified limit.

Domain Knowledge

In the absence of constraints on the vertical rate, the *trajectory* is calculated using a default climb performance that is considered to fit best the unconstrained profile. Such a climb profile may be overridden by instructions that implicitly or explicitly require the application of a different *VRC*.

Expedited climbs/descents require the application of an enhanced *VRC* until either a specified level or to the *CFL*. An entered specified maximum *VRC* is applied if the currently applied rate is greater and an entered specified minimum *VRC* is applied if the currently applied rate is less.

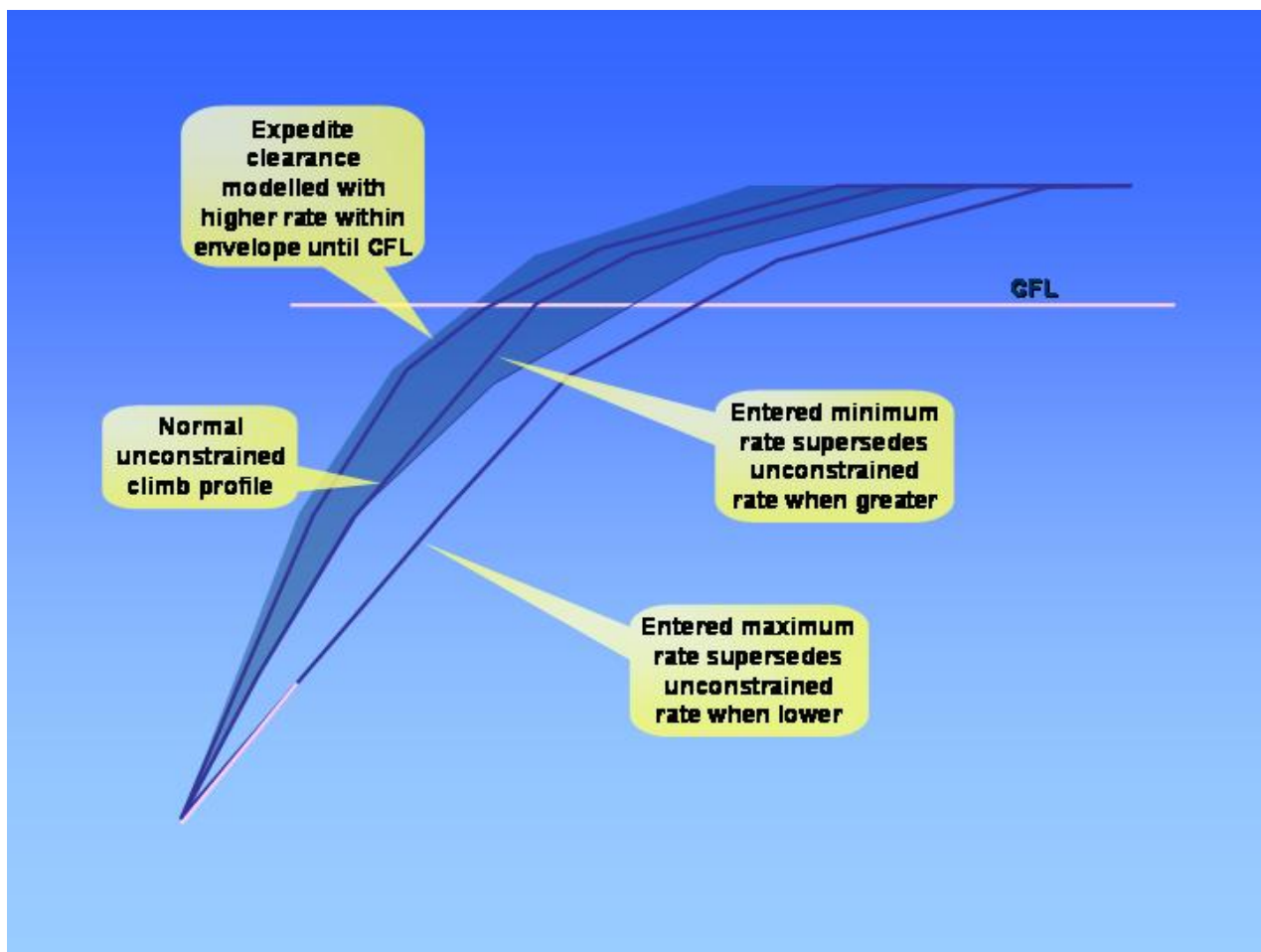


FIGURE 11 – VERTICAL RATE OF CHANGE

Assumptions

The system allows entry of vertical rate and expedite climb/descent instructions from controller input.

The systems allows the definition of expedited climb/descent rates for aircraft types or a way of approximating them from nominal rates.

The system provides the capability to enter adaptation data that meets the requirements of military combat traffic, e.g. climb rates, turns and speeds.

2.3.5 Hold (3.3.5)

The system incorporates entered holding instructions in the trajectory.

Domain Knowledge

A flight enters a holding pattern when it is not cleared to proceed beyond a specified point. This occurs either:

- at the clearance limit (normally the Initial Approach Fix) prior to commencing intermediate approach, or
- enroute when so instructed by ATC.

Where used in approach the holding pattern is often referred to as a stack, with aircraft typically entering at the top, descending through successive levels to exit and commence their descent from the bottom. There is therefore a discontinuity between the segments prior to holding and post holding.

Assumptions

The system allows entry of hold instructions, including optional holding point fix and expected holding duration or end time from controller input.

2.3.6 Assigned Heading or Track (3.3.6)

On entry of an assigned heading, the route is modified from the current aircraft position, following the derived ground track for the likely duration of the clearance, and subsequently turning to rejoin the original route.

Domain Knowledge

A heading is an instruction to orientate the fore and aft axis of the aircraft on to a specified magnetic bearing; a track is an instruction to follow a path over the surface oriented at the specified magnetic bearing. They are the same if there is no wind vector.

Any instruction to route to a specified point or to resume own navigation terminates an assigned heading or track instruction. In the case of a "Resume Own Navigation" input, criteria are applied to determine the point at which the *planned trajectory* is expected to be rejoined. Examples include:

- First *significant point* in the next sector.
- Point at which the re-joining angle is less than a parameter value.

In the case that default conditions are used to close the trajectory when no heading duration is entered, care must be taken to avoid that new posting and/or conflicts are erroneously detected by the system based on an incorrect assumption. These might lead to unwanted triggering of coordination and/or warnings, which then have to be withdrawn when the resume order is given. Such oscillations impact on controller workload and may reduce controller trust in the system.

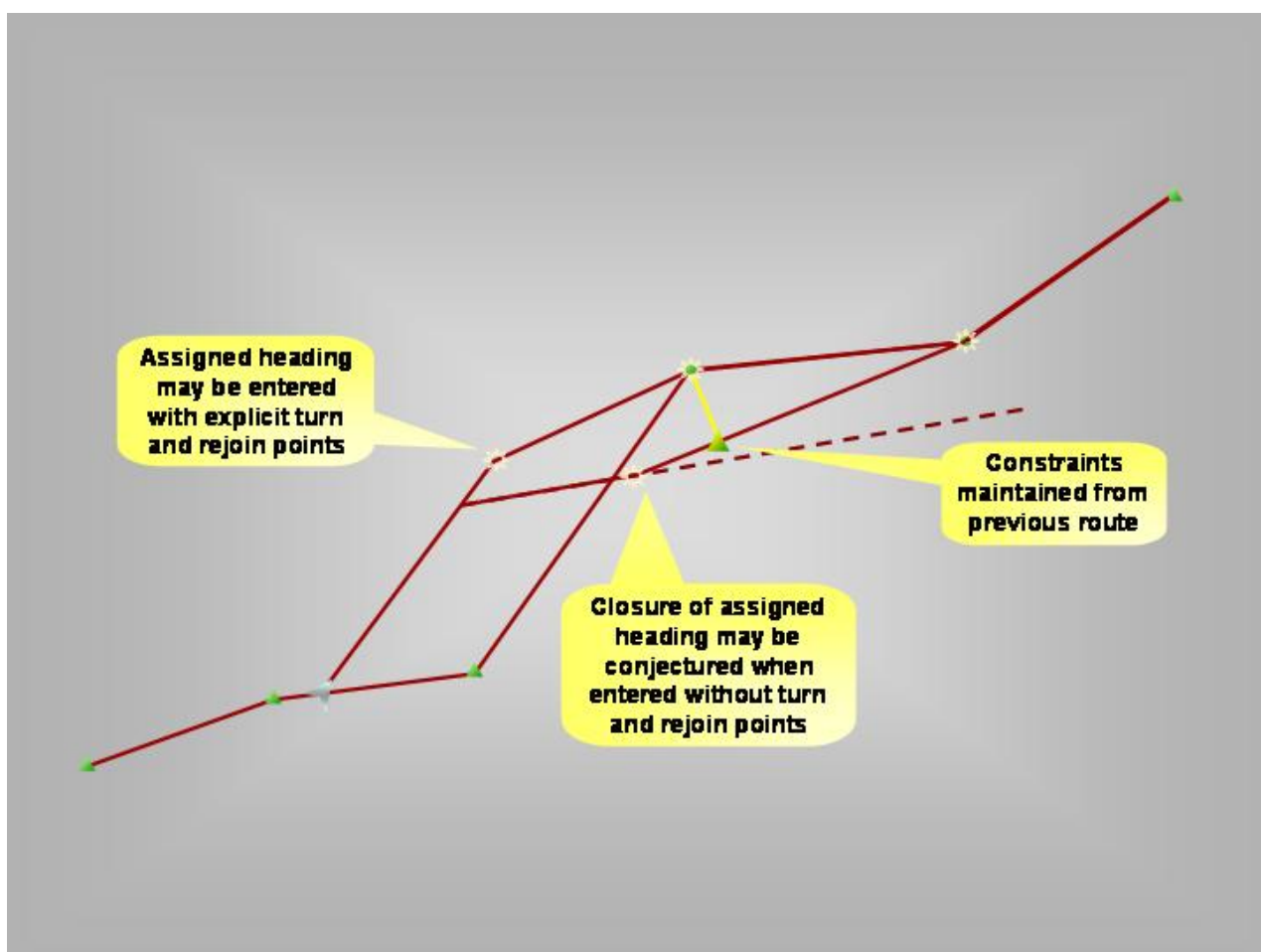


FIGURE 12 – ASSIGNED HEADING

Where an assigned heading is expected to be of a short duration, these might be entered as open instructions and not necessarily applied to the planned trajectory. Where the duration of the heading is likely to have an impact on the sector sequence or conflict detection, the heading is expected to be entered as a closed instruction (e.g. with the use of an elastic vector to specify the expected next turning point) and is applied to the planned trajectory.

Assumptions

The system allows controller input of Assigned Heading and Assigned Track.

The system provides the capability to enter adaptation data that meets the requirements of military combat traffic, e.g. climb rates, turns and speeds.

2.3.7 Assigned Speed (3.3.7)

An assigned speed is applied to the trajectory until the conditions for termination apply.

Domain Knowledge

In the absence of constraints on speed, the *trajectory* is calculated using a default speed profile that is considered to fit best the unconstrained performance. Such a speed profile may be overridden by controller instruction specifying the maintenance of the current or a specified speed.

An assigned speed is applicable until the termination conditions (if entered) are met, e.g. until passing/reaching a specified level or until passing a specified point, or until explicitly cancelled. In respect of open speed constraints:

- those applied before *TOC* are closed at *TOC*;
- those applied before the final *TOD* are closed at *TOD*;
- those applied in the descent phase are closed at the *IAF*;
- those applied after the *IAF* are applied until a specified point on final approach.

Where a specified airspeed or a maximum or minimum airspeed constraint is entered and the speed used in the calculation of the *trajectory* is not compliant, the *trajectory* is recalculated to comply with the constraint by using the entered value.

Strategic speed constraints may be removed by controller instruction; this applies frequently in respect of departures within *TMA* airspace.

An alternative to applying the assigned speed directly to the trajectory might be to allow the trajectory recalculation to take place once the speed change is detected by monitoring aids.

Assumptions

The system allows controller input of Assigned Speed as an absolute, minimum or maximum speed, expressed as an airspeed, with optional termination conditions.

The system provides the capability to enter adaptation data that meets the requirements of military combat traffic, e.g. climb rates, turns and speeds.

2.3.8 Assigned Route or Direct (3.3.8)

An assigned route replaces the original route between the specified start and end points and the new planned trajectory is calculated.

Domain Knowledge

A controller might assign a rerouting to a flight due to airspace restrictions, for traffic avoidance, to grant a shorter route (direct), or in response to aircrew request. The rerouting might take place with immediate effect (i.e. from the current aircraft position) or at a designated start point, and ends at a designated point at which the original *route* is regained.

Diversions are a special case whereby the original *route* is not regained; the *route* to the diversionary aerodrome is specified or determined automatically and the new *trajectory* calculated.

Assumptions

The system allows controller input of *route* amendments either by as direct *route segments* from one point on the *route* (or present position) to another, or by using *ATS route* identifiers (including *CDRs*). The semantics of the modified *route* are verified and, if the *route* is error free, the *trajectory* is recalculated.

2.3.9 Missed Approach Processing (3.3.10)

The system determines the trajectory of a flight performing a missed approach procedure.

Domain Knowledge

In the case that a flight, having commenced its approach to land, has to terminate its approach prematurely (e.g. due to the runway being blocked, the aircraft not being ready in its landing configuration, etc), the aircrew declare a missed approach and follow a published missed approach procedure that takes the aircraft to a designated holding point.

The *trajectory* to be flown following a missed approach is determined from the arrival runway. It would normally consist of a short fixed *route*, probably altitude and speed constrained, back to the initial approach fix.

Assumptions

The trigger for the missed approach might be manual input from the controller after having been informed by the aircrew, or the automatic detection of the track climbing or existing after the expected landing time.

The system contains a database of missed approach procedures indexed by landing runway, specifying the route and strategic constraints to a point at which the approach can recommence.

2.3.10 Tactical Parallel Offset (3.3.10)

The system applies entered tactical parallel offset clearances, if provided, to the planned trajectory.

Domain Knowledge

Flights equipped with a suitable RNAV capability may be instructed to fly a tactical parallel offset a specified distance left or right of an *ATS route* and later to resume normal navigation as an alternative to applying radar vectors, for example to allow an aircraft to climb through the level of another aircraft on the same route.

The point to leave the original *route* in order to attain the offset may be specified in the constraint; otherwise an immediate transition may be assumed. Similarly, the point at which the aircraft rejoins the original route may be specified in the constraint or may otherwise be the system exit coordination point or the last point prior to the *STAR*).

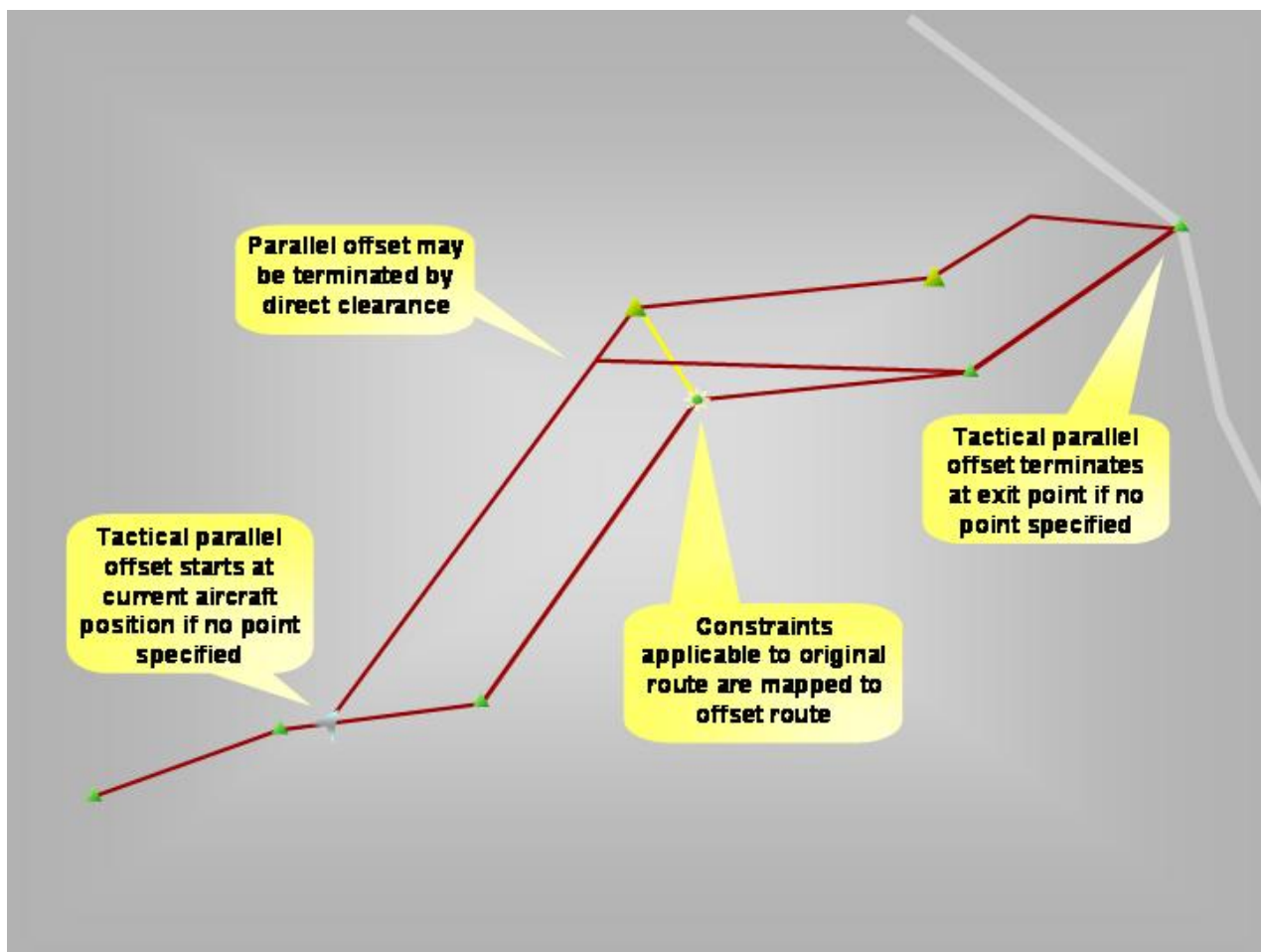


FIGURE 13 – TACTICAL PARALLEL OFFSET

Assumptions

The system allows controller input of a tactical parallel offset command containing optional start and end (“resume own navigation”) points. The size of the offset is predefined, dependent on the separation minima.

2.3.11 Time Constraints (3.3.11)

The system applies entered time constraints to the trajectory.

Domain Knowledge

A time constraint at a specified point might be entered due to a flight entering airspace in which procedural control is applied, or might be received as a result of arrival management or from an oceanic clearance.

Where such a constraint is applied at a specified point, the *trajectory* is adjusted within the normal operating envelope of the flight to meet the constraint. The calculation is made using the current vertical profile, i.e. a vertical transition to a lower level to allow a greater speed reduction is not performed.

A warning is generated if the constraint cannot be met by speed adjustment.

Assumptions

The system contains a database of performance envelopes that define the minimum and maximum speeds that can be flown by each aircraft type in order to comply with a time constraint. A change to the longitudinal speed might incur a corresponding change to climb/descent performance.

The system allows controller input of a time constraint, containing the point and corresponding required time over. The system allows time constraints to be applied by the arrival manager and received in oceanic clearances.

2.4. Climb and Descent Rules (3.4)

The profile is modelled on the assumption that the aircraft will climb as early as possible and descend as late as possible to meet its constraints.

Domain Knowledge

In general, the most efficient flight profile for an aircraft is to climb immediately with a predetermined speed regime to the requested level, and to maintain this level as long as possible prior to starting its descent. ATC facilitate the achievement of the optimum profile where possible, though constraints might have to be applied due to procedures (*strategic constraints*) or other traffic (*tactical constraints*).

The climb and descent profiles are modelled on the principle of the climbing as early as possible and descending as late as possible using the preferred aircraft/airline performance envelope where possible, whilst complying with applicable constraints.

Changes to the requested flight level at certain points on the route might be filed in the flight plan and are modelled in the planned trajectory (as amended *enroute cruising levels*) when cleared by the controller on result of aircrew request, or if required by ATC procedure (e.g. in accordance with the levels applicable to the route). The latter case can be achieved by a specialization of the strategic constraints described in 3.2.3.

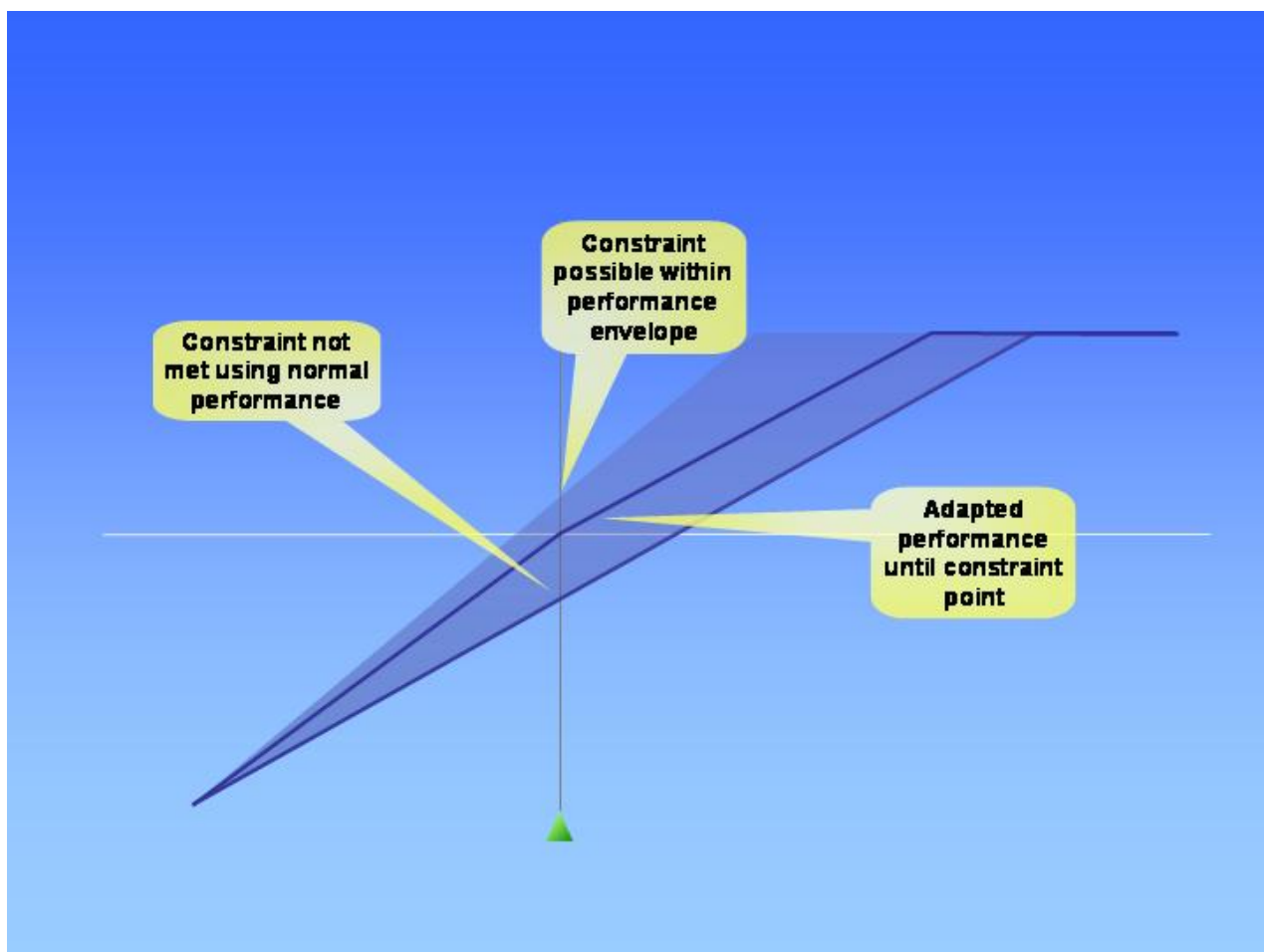


FIGURE 14 – PERFORMANCE ENVELOPE

Assumptions

The system contains a database of nominal performance parameters that define the most likely climb and descent rates flown by each aircraft type in the absence of constraints. These nominal performance parameters might be further specialized by other criteria such as airline, flight duration, etc. in order to improve the accuracy of the trajectory calculation.

A warning of an unachievable constraint should only be provided when it takes into account the performance envelope of the aircraft, thereby avoiding a proliferation of nuisance warnings.

The system provides the capability to enter adaptation data that meets the requirements of military combat traffic, e.g. climb rates, turns and speeds.

If, in order to meet a constraint, a climb or descent performance is required above the normal performance but within the performance envelope of the aircraft, the climb/descent is modelled assuming that the constraint will be achieved.

Domain Knowledge

On occasion, a constraint will require a climb or descent performance steeper than preferred, but within the performance envelope of the aircraft.

Assumptions

The system contains a database of performance envelopes that define the maximum climb and descent rates that can be flown by each aircraft type in order to comply with a constraint.

2.5. Integration of Progress and Deviation (3.5)

The trajectory is recalculated using the most recent timing and progress information when this becomes available.

Domain Knowledge

After the flight plan is filed, the flight might be subjected to a flow management restriction and given a Calculated Take-Off Time (CTOT) by the Central Flow Management Unit (CFMU). For the purpose of the planned trajectory, the CTOT is used as the new departure time, superseding the previous estimate. The CTOT might subsequently be revised or cancelled.

For flights that enter the Area of Responsibility (AoR), the entry details (entry point, level and time) are passed by the ATS unit responsible for the flight up to the AoR boundary, either by means of OLDI messaging (e.g. ABI, ACT and REV messages) or by verbal coordination. In the absence of more reliable information, the time passed by the previous ATS unit is used as a reference to update the planned trajectory. However, if the progress of the flight is already being monitored by means of the system track (by a function known as Monitoring Aids), the times calculated from the monitoring is considered more reliable than that passed by the previous ATS unit.

Once the Monitoring Aids are monitoring the progress of the flight, the estimated times in the planned trajectory can be further refined by integrating any delay or advance of the detected aircraft position compared to the expected position and by amending the speed profile using the velocity contained in the track state vector. Similarly, the vertical profile can be updated using the vertical position and rate contained in the track state vector. The requirement does not specify the details of the capability to be provided as they are considered matters of system design in achieving the accuracy requirements that are specified in section 4.

Assumptions

The system allows entry, revision and cancellation of CTOT from slot allocation messages, slot revision messages and slot cancellation messages received from the Enhanced Tactical Flow Management System (ETFMS).

The system receives OLDI messages from neighbouring centres and allows controller input of boundary estimates.

The system contains a Monitoring Aids function that monitors conformance of the track with the planned trajectory and updates the latter as necessary.

The climb and descent profiles are recalculated according to the actual manoeuvres performed by the aircraft.

Domain Knowledge

In order to ensure safety, the air traffic controller often clears a flight in climb phase in short bursts that are known to be safe, and as the aircraft approaches its cleared level or the “threat” passes, a new clearance is given to continue the climb to a further level. In a similar way, where an aircraft climbs through a number of layered sectors, although each controller might only clear the aircraft to the last level of his own sector, the controller of the sector above, having been transferred the flight shortly before it reaches cleared level, might grant a clearance continue the climb through his own sector. For this reason, the cleared level is not normally applied to the trajectory (see paragraph 2.3.3 of these guidelines).

Clearly however, there will be cases where an aircraft has to level-off at an intermediate cleared level to ensure separation from an aircraft above and in these cases it is possible, once the level-off is detected, to refine the planned trajectory by applying it for a short period.

As aircraft generally cruise more efficiently at higher levels, where possible the controller often gives a clearance to the aircraft to descend “when ready”. This allows the aircraft to determine its most efficient descent profile, which is usually to descend as late as possible with the engines on idle. Therefore, the cleared level is also not normally applied to the trajectory in the descent phase.

However, once the aircraft commences its descent, the accuracy of the planned trajectory might be improved by modelling the descent to the cleared level, then levelling-off and applying the normal principle of descending as late as possible.

Assumptions

The system contains a Monitoring Aids function that detects when an aircraft levels-off at its cleared level.

The system contains a Monitoring Aids function that detects when an aircraft commences its descent towards its cleared level.

The flight path of an aircraft having been instructed to turn is corrected for effects of turn delay and wind drift once the turn is completed.

Domain Knowledge

When a controller instructs a flight to turn on to a particular heading or direct to a waypoint, there is a delay before the aircraft is established on the heading/track comprising the time necessary to pass the instruction, for the aircrew to receive and acknowledge the instruction and to command the manoeuvre of the aircraft (via the FMS, auto-pilot or manually), and for the aircraft to perform the manoeuvre.

This delay might be approximated in the modelling of the *planned trajectory* when the instruction is entered by the controller, but, as each element is variable, the accuracy can be further improved by refining the trajectory during, or on completion, of the manoeuvre.

The actual ground track (the path over the surface) followed by an aircraft that has been assigned a heading is dependent on the wind effect on the aircraft; inaccuracies in the modelling of the wind by the system will manifest in inaccuracies in the modelling of the horizontal path. Once the aircraft is established on an assigned heading, the accuracy of the planned trajectory might be improved by integrating the actual track of the aircraft.

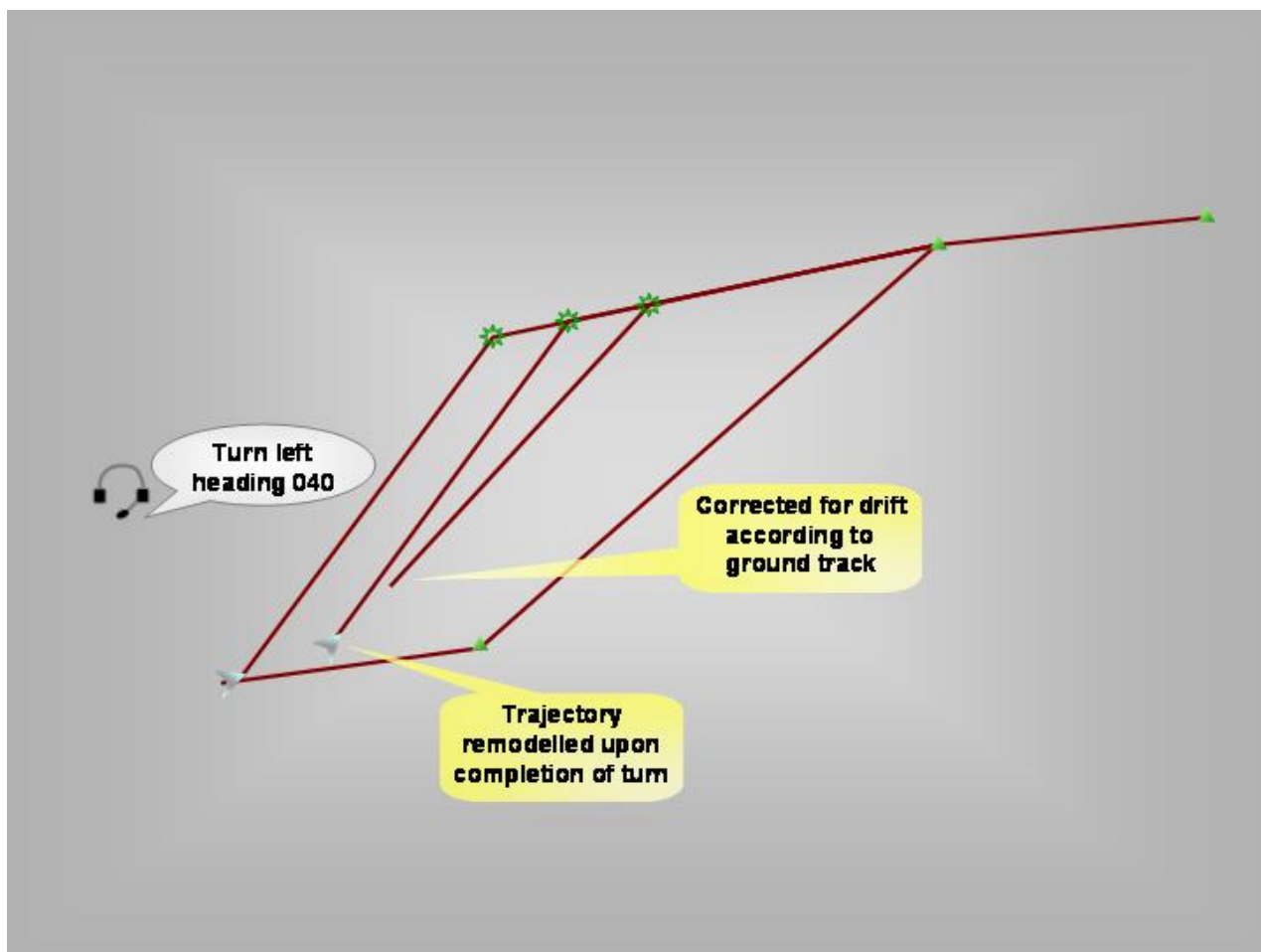


FIGURE 15 – TURN CONFORMANCE

Assumptions

The system contains a Monitoring Aids function that detects when an aircraft has completed its turn towards an assigned heading or direct to a waypoint.

The system contains a Monitoring Aids function that determines the ground track of an aircraft.

2.6. The Tactical Trajectory (3.7)

The tactical trajectory projects the current clearance from the aircraft position over the tactical trajectory prediction horizon.

Domain Knowledge

Whereas the *planned trajectory* notionally represents the most likely aircraft behaviour, particularly for the purpose of sector planning, the *tactical trajectory* provides a short-term projection of the current clearance of the flight that is more akin the tactical controller's projection of the flight when scanning for conflicts.

The *tactical trajectory* starts at the current aircraft position and projects the current clearance over a defined look-ahead time (tactical trajectory prediction horizon) or to the extent of the Aol of the subject sector. In the case that the aircraft is cleared in accordance with the *planned trajectory*, the *tactical trajectory* might be identical to the corresponding portion of the *planned trajectory*.

In cases where a clearance is given to follow a given routing, the *tactical trajectory* routes from the current aircraft position to the next and subsequent points on the *route* over the prediction horizon. Where an aircraft is cleared direct to a point not on the planned *route*, or on a heading, the *tactical trajectory* starts at the aircraft position and continues in the direction of the direct point or heading for the complete prediction horizon; no attempt is made to regain the *planned trajectory*.

The *tactical trajectory* always respects the current *CFL*. Starting from the current aircraft position, the *tactical trajectory* climbs or descends and then maintains the *CFL*.

Where a series of level instructions are given such as in the definition of a *SID*, the final level is maintained until a different *CFL* is issued.

Level restrictions included in the description of a *SID* or issued as part of the departure clearance are *CFLs* and are modelled by the *tactical trajectory*.

To increase the accuracy of the tactical trajectory, the system might provide an instruction entry delay following entry of a new clearance. This delay would use the previous clearance data to build the trajectory for an adaptable time before re-calculating the trajectory based on the newly issued clearance. This delay allows for transmission of the clearance to the pilot and time for the pilot to action the clearance.

Assumptions

A surveillance function is available that provides the position of the aircraft on a periodic basis.

3 TRAJECTORY ACCURACY REQUIREMENTS

3.1. Principles and Process

The performance of the TP is evaluated by means of a statistical analysis on a large sample of data in order to reduce the effect of individual anomalies, quantifying accuracy by means of a number of KPIs.

The flight intent described by the functional requirements does not state how the aircraft will be flown (termed the “aircraft intent”). Various studies have quantified the sensitivity of the trajectory to factors of aircraft intent such as thrust settings, speed regime, aircraft mass, etc, which contribute to the variability of the flown trajectories.

The measurement of trajectory accuracy is performed by comparing truth data, in the form of radar tracks, with calculated and updated trajectories.

The initial trajectory calculated for a flight together with all the updated trajectories corresponding to planning amendments, coordination, tactical instructions and progress/conformance monitoring are recorded and time-stamped for use in the analysis. Although there will be a small error in the track data, this is considered to be insignificant when compared to the trajectory.

Portions of flights are selected where the flight is cleared, and the aircraft operated, in accordance with the flight intent as described by the functional requirements.

As stated above, for the purpose of this performance requirement it is assumed that the flight intent is correct and therefore only those portions of trajectories where the aircraft is operated in accordance with the flight intent will be selected for accuracy measurement. This implies, for any point that is being measured, the earliest calculated trajectory that can be measured is that corresponding to the last controller instruction that affects the path to the measured point. For example, for a flight being given a stepped climb, the earliest trajectory that might be used for the measurement of accuracy of the point at which the aircraft reaches FL300 is that corresponding to the clearance to climb to a level beyond FL300. Several updated trajectories might also exist for the flight in the period prior to reaching FL300, corresponding to conformance updates made by the monitoring aids.

Performance is specified for three basic metrics (longitudinal, lateral and vertical accuracy), applicable to both the planned and tactical trajectories, and specializing these with various conditions under which they are measured.

Three components of accuracy are identified corresponding to the longitudinal, lateral and vertical dimensions, and these are measured under a number of different conditions (e.g. longitudinal accuracy is measured for aircraft in level flight, for climbing aircraft, and for descending aircraft), termed “specializations”. The TP is also expected to make use of certain information such as meteorological conditions, track state vectors, etc, the accuracy of which is declared via input metrics.

The derivation of signed mean error indicates any bias present in the trajectory calculation. The standard deviation of the error indicates the spread of the error and can be used to calculate the limits of an aircraft position at a given moment in time with a given probability. The peak error might indicate an incorrect logic or aircraft model, or the deviation of the aircraft from the flight intent.

The modelling of the horizontal flight path is defined by functional requirements and is therefore not the subject of accuracy requirements.

3.2. Basic Metric – Longitudinal Error (4.1)

Longitudinal error represents the difference between the estimated progress at a point in time determined from the trajectory and the actual progress determined by the system track. Measurements are taken at fixed intervals over a defined period for aircraft in cruise, climb and descent phases. In all cases, the measurements are taken only when the aircraft is in conformance with the flight intent for the duration of the measurement period.

The primary user of this metric is the medium-term conflict detection function as it defines the uncertainty in the information from which conflicts are derived.

3.2.1 Input Metrics (4.1.1)

Meteorological conditions, normally in the form of a 3-dimensional grid containing wind velocity and temperature, are known with a given error.

The track state vector is correlated with the flight data and has a known error.

The flight intent is known and static and the aircraft is in conformance with the flight intent over the complete measurement.

3.2.2 Output Metrics (4.1.2)

Specialization

Measurements are taken independently in cruise, climb and descent phases. For aircraft in cruise, a measurement point is selected that is sufficiently far inside the Area of Interest (AoI) to allow measurement over the maximum measurement horizon. In climb and descent phases, measurement points are selected where the aircraft crosses certain flight levels. These flight levels might either be predetermined (e.g. at 5000 feet intervals between FL200 and FL400) or determined for each flight as a function of its cleared levels in order to maximize the available measurement horizon (e.g. for an aircraft currently at FL110, cleared to FL280, measurement points might be selected at FL200, and FL270). In this latter case, the results will be banded (e.g. at FL200 – FL240, FL250 – FL290, etc.).

The aircraft should be unconstrained in speed.

Derivation

Peak error, signed mean error (bias) and standard deviation of the error is derived for the sample, measuring the error for each flight at one minute intervals over a maximum horizon of 20 minutes.

3.2.3 Measurement Approach

As with the other metrics that follow, a fundamental aspect of these measurements is to be able to isolate portions of flights where the flight intent is stable and the aircraft is operated in conformance with the flight intent. When an aircraft's planned route is changed (e.g. upon being given a direct clearance) the trajectories calculated prior to the change are invalidated. The measurement horizon is therefore limited by such amendments.

The process assumes that system tracks and trajectories are recorded in an operational environment (e.g. from the operational ATC system or a system that is operating in a shadow mode) such that the trajectory is kept updated by controller inputs and by the longitudinal re-conformance from the monitoring aids.

The suggested measurement process comprises the following steps:

1. Each flight shall be processed in turn, determining the segments in which the flight is performed in conformance with the trajectory and recording the errors at one minute intervals over the conformant segments.
2. The conformant segments shall be determined as the portion of the trajectory starting from the timestamp of the trajectory until the time at which the flight is non-conformant laterally or vertically with the trajectory.
3. The error in longitudinal position at one minute intervals over the conformant segment shall be calculated and stored per flight phase and, in climb and descent phases, per 5000 feet band in which the vertical position is located.
4. The peak error, mean error and standard deviation of error per prediction time/level band for the complete sample shall be calculated.

This process is depicted in Figure 16 below.

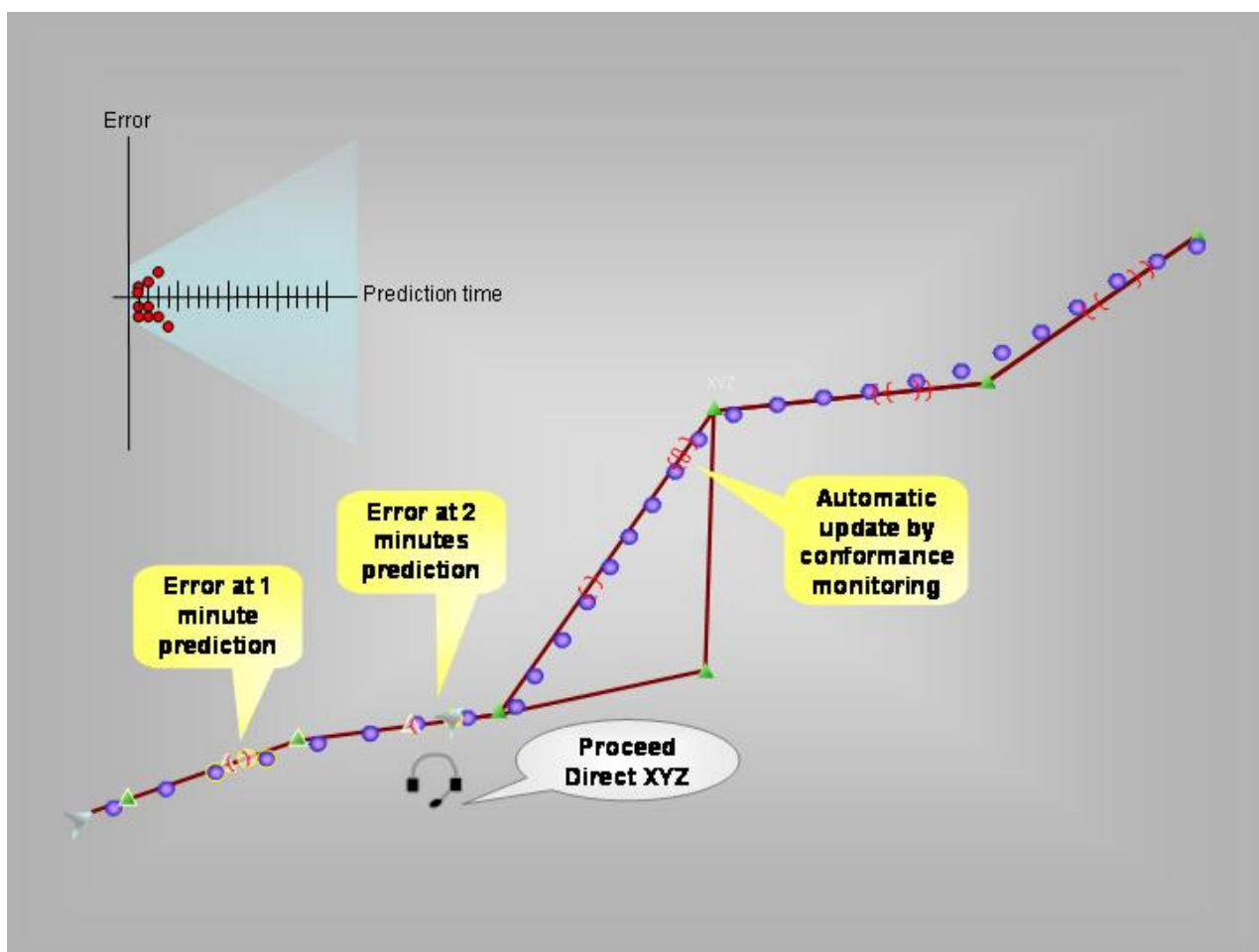


FIGURE 16 – LONGITUDINAL ERROR MEASUREMENT

3.2.4 Alternative Measurement Approaches

In case it is impractical to record trajectories in a live or shadow mode environment, the trajectories may be re-created offline, providing that a behaviour representative of the operational behaviour is achieved. In order to ensure that the trajectory is measured only when the aircraft is flown in accordance with the flight intent, this might be performed by generating a trajectory each minute from the time at which a tactical instruction is entered, starting at the point at which a trajectory track position with the timestamp closest to the trajectory calculation time, selecting as a measurement point, some point prior to the entry of a subsequent tactical instruction.

In case the trajectory recalculation is not synchronized with the selected measurement point, the results will be banded together in one-minute bands.

3.3. Basic Metric – Vertical Error (4.2)

Vertical error is measured in terms of the difference between the estimated vertical position at a moment in time as determined from the trajectory and the actual vertical position of the aircraft at that moment in time, and is a result of the vertical rate used by the trajectory prediction differing to the actual vertical rate.

As with longitudinal error, measurements are taken at fixed intervals over a defined measurement horizon. Measurement points are taken at FL 250 and FL 300, with measurements starting only once the aircraft has a continuous climb/descent through the measured level. Note that this does not necessarily imply that the aircraft need be cleared immediately through the measured level, providing that subsequent clearances are issued in sufficient time that the vertical rate has not reduced for stopping at an intermediate level.

The primary user of this metric is the medium-term conflict detection function as it defines the uncertainty in the information from which conflicts are derived.

3.3.1 Input Metrics (4.2.1)

Meteorological conditions, normally in the form of a 3-dimensional grid containing wind velocity and temperature, are known with a given error.

The track state vector is correlated with the flight data and has a known error.

3.3.2 Output Metrics (4.1.2)

Specialization

Measurement points are selected where the aircraft crosses certain flight levels. These flight levels might either be predetermined (e.g. at 5000 feet intervals between FL200 and FL400) or determined for each flight as a function of its cleared levels in order to maximize the available measurement horizon (e.g. for an aircraft currently at FL110, cleared to FL280, measurement points might be selected at FL200, and FL270). In this latter case, the results will be banded (e.g. at FL200 – FL240, FL250 – FL290, etc.).

Measurements start once the aircraft is cleared through the measurement level or is cleared in steps with each step being issued in sufficient time that an intermediate level-off is not initiated and such that the level in the first step is beyond any applicable strategic constraint between the aircraft level and the measurement level.

The aircraft should be unconstrained in vertical rate.

Derivation

Peak error, signed mean error (bias) and standard deviation of the error is derived for the sample, measuring the error for each flight at one minute intervals over a maximum horizon of 20 minutes.

Measurement Approach

The fundamental prerequisite for the measurement of vertical error is that the aircraft has a continuous climb to (and beyond) the measurement level. This requires that the aircraft is either cleared directly beyond the measurement level or is given a stepped climb but each further clearance is issued before the aircraft commences its level-off. This also requires that there are no strategic constraints modelled by the trajectory before the measurement level; if constraints were applicable, the aircraft must be cleared beyond the constraint such that the constraint is removed from the trajectory (see Section 2.3.3 of this Annex).

The suggested measurement process comprises the following steps:

1. Each flight shall be processed in turn, determining the segments in which the flight is performed in conformance with the trajectory and recording the errors at one minute intervals over the conformant segments.
2. The conformant segments shall be determined as the portion of the trajectory starting from the timestamp of the trajectory until the time at which the flight is non-conformant laterally or vertically with the trajectory.
3. The error in vertical position at one minute intervals over the conformant segment shall be calculated and stored per flight phase and, in climb and descent phases, per 5000 feet band in which the vertical position is located.
4. The peak error, mean error and standard deviation of error per prediction time/level band for the complete sample shall be calculated.

This process is depicted in Figure 17 below.

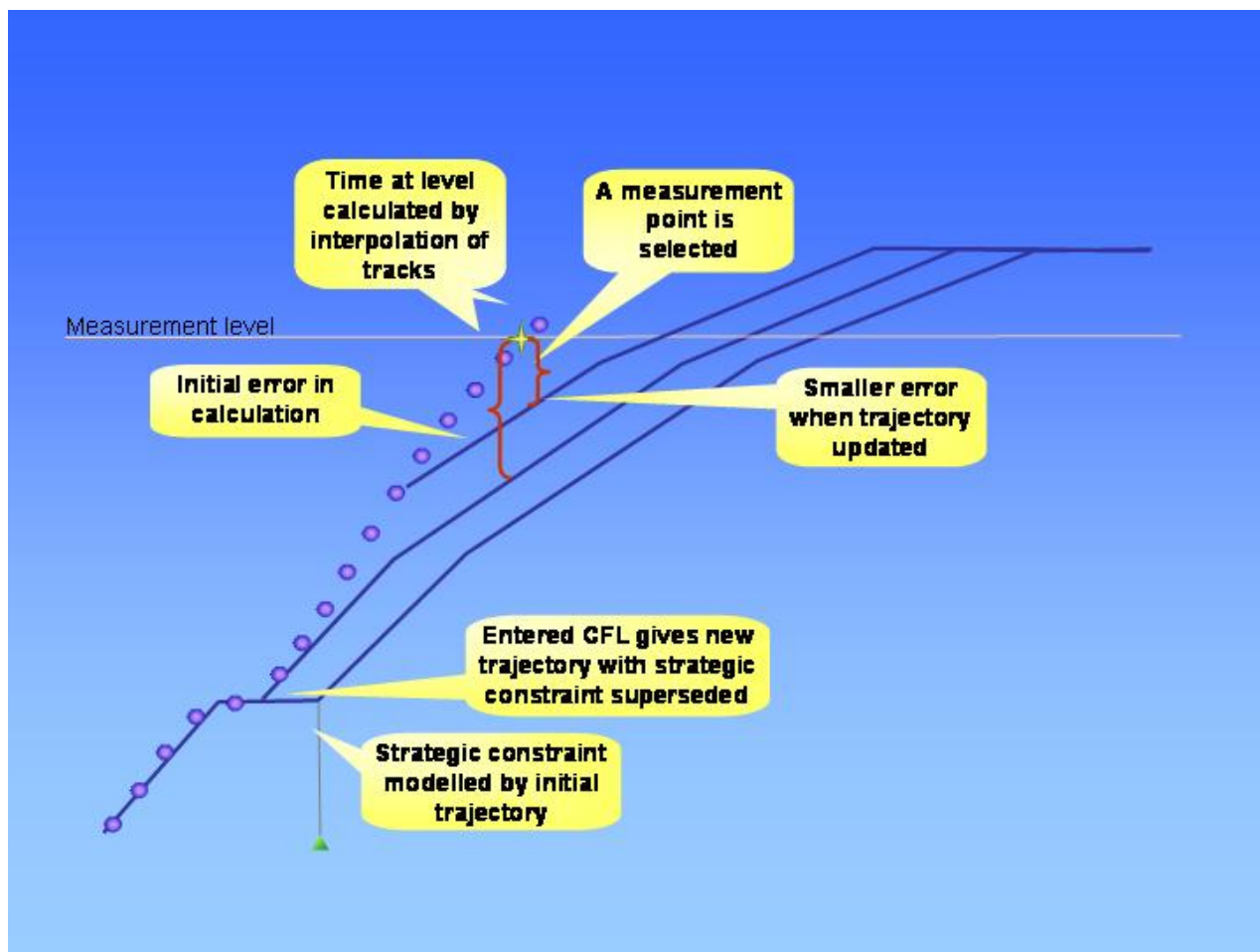


FIGURE 17 – VERTICAL ERROR MEASUREMENT

Alternative Measurement Approaches

In case it is impractical to record trajectories in a live or shadow mode environment, the trajectories may be re-created offline, providing that a behaviour representative of the operational behaviour is achieved. In order to ensure that the trajectory is measured only when the aircraft is flown in accordance with the flight intent, this might be performed by generating a trajectory each minute from the time at which the aircraft is cleared beyond the selected measurement level, starting at the point at which a trajectory track position with the timestamp closest to the trajectory calculation time.

In case the trajectory recalculation is not synchronized with the selected measurement point, the results will be banded together in one-minute bands.

3.4. Basic Metric – Lateral Error (4.3)

Lateral error represents the perpendicular offset of the aircraft position from the 2-d path described by the trajectory. For aircraft navigating according to published routes and waypoints, Section 2.1.3 specifies requirements for deriving the 2-d path from the flight intent, and therefore no measurement of accuracy is applicable. However, when an aircraft is instructed tactically to fly direct to a point, or to fly a specified heading or track, the 2-d path is made uncertain by factors such as the delay before the manoeuvre is executed, the rate of turn and, in the case of an assigned heading, the drift caused by the wind. The system is expected to correct for these sources of error through monitoring aids as described in [MONA Spec].

The primary user of this metric is the tactical role of the medium-term conflict detection function.

3.4.1 Input Metrics (4.3.1)

Meteorological conditions, normally in the form of a 3-dimensional grid containing wind velocity and temperature, are known with a given error.

The track state vector is correlated with the flight data and has a known error.

3.4.2 Output Metrics (4.3.2)

Specialization

Measurements for a flight commence upon a trajectory update corresponding to entry of a direct, heading or track clearance. Measurement points are selected at one minute intervals along flown 2-d path as defined by the system tracks. Over a defined horizon or until the next tactical ATC instruction is entered.

The perpendicular offset of each measurement point from the 2-d path described by the trajectory is measured at one minute intervals until a subsequent tactical instruction is entered.

Derivation

Peak error, signed mean error (bias) and standard deviation of the error are derived for the sample, measuring the error for each flight at one minute intervals over a maximum horizon of 10 minutes.

Measurement Approach

The process assumes that system tracks and trajectories are recorded in an operational environment (e.g. from the operational ATC system or a system that is operating in a shadow mode) such that the trajectory is kept updated by controller inputs and by the longitudinal re-conformance from the monitoring aids.

The suggested measurement process comprises the following steps:

1. A trajectory sample shall be created containing trajectory portions where direct clearances, and assigned heading or track are tactically applied, and the associated correlated system tracks.
2. Measurement points are selected at one minute intervals commencing one minute after the trajectory update corresponding to the entry of the tactical instruction, up to the full measurement horizon of the entry of a subsequent tactical instruction. The position of the measurement point shall be calculated by interpolation of the tracks with timestamps preceding and succeeding the measurement time.
3. The lateral error in terms of the perpendicular offset of each measurement point from the trajectory shall be recorded at one minute intervals.
4. The peak error, mean error and standard deviation of error at each minute for the complete sample shall be calculated.

This process is depicted below.

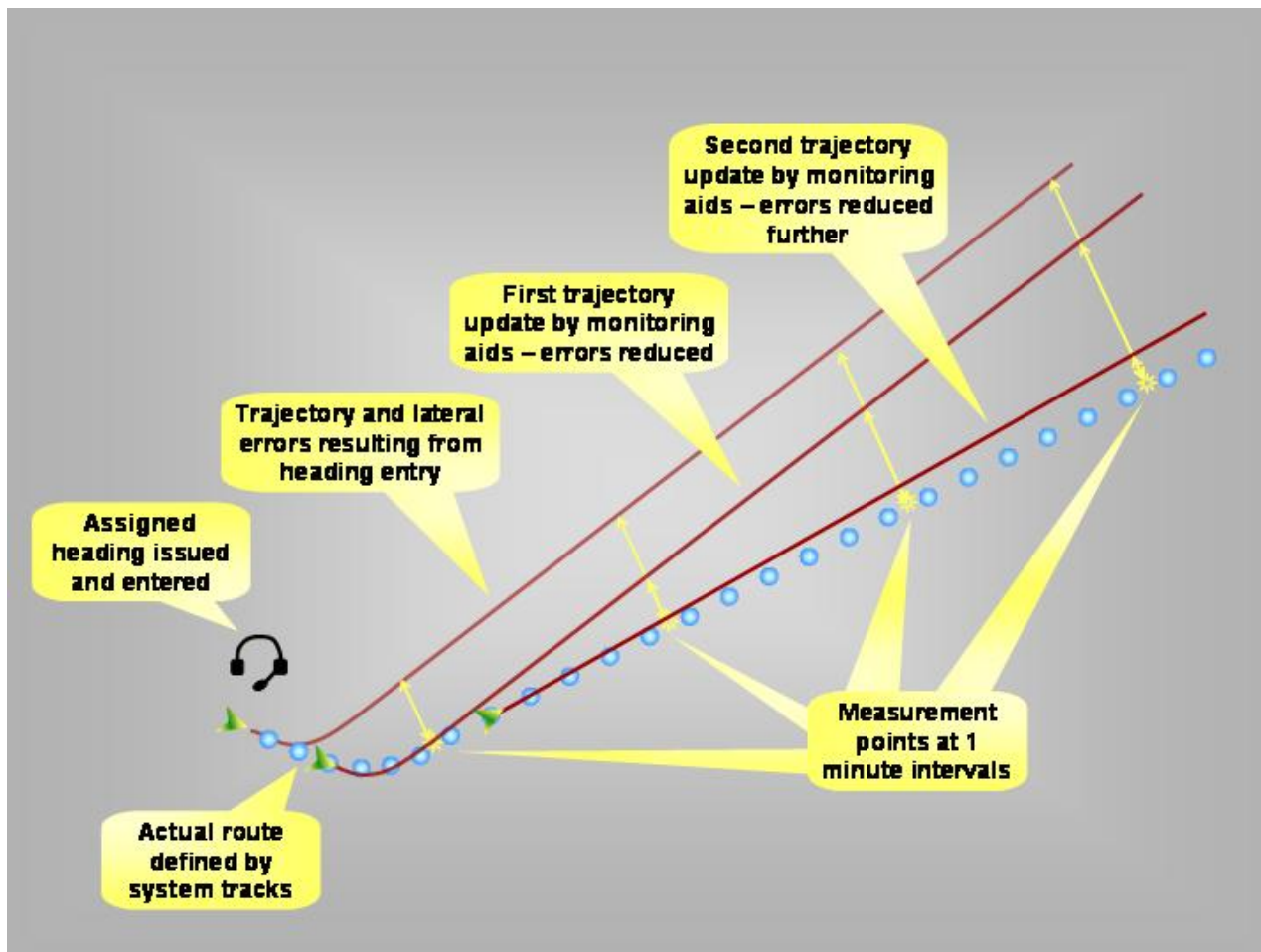


FIGURE 18 – LATERAL ERROR MEASUREMENT



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