

**CND/COE/  
AT/AO**



**Point Merge Integration of  
Arrival Flows Enabling  
Extensive RNAV Application  
and Continuous Descent  
-  
Operational Services and  
Environment Definition**

**CND/COE/AT/AO  
ATC Operations and Systems**

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## DOCUMENT CHANGE LOG

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**NOTICE TO AIR NAVIGATION SERVICE PROVIDERS:**

The procedure described in the present document involves a change in terminal airspace structures.

The EUROCONTROL ‘Terminal Airspace Design Guidelines’ document (Ref [9], Part A, §2.2) emphasises the following general principles as being the six ‘cornerstones’ of the terminal airspace design process:

- Safety shall be enhanced or at least maintained by the design of (or alteration to) a terminal airspace;
- Terminal airspace design should be driven by Operational requirements;
- Without prejudice to the safety principle above, whether and to what extent consideration shall be given to environmental impact when designing a terminal airspace is to be decided by State policy;
- The design of a terminal airspace should be undertaken in a collaborative manner;
- Terminal airspace should be designed, where possible, so as to be integrated into the airspace continuum both vertically and laterally without being constrained by state boundaries;
- Terminal airspace should be designed following a clear design methodology within the greater context of a terminal airspace design process.

In particular, stakeholders implementing any terminal airspace change should ensure that they factor into their planning any obligations to consult communities affected by any resulting changes to environmental impact and where relevant, other interested parties (e.g. planning authorities, statutory agencies, Non-Governmental Organisations (NGOs) and environmental regulators). This may require the consideration of alternative operational solutions and justification of the proposed option.

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## 1. Introduction and document information

### 1.1 Document purpose

The present document constitutes the Operational Services and Environment Definition (OSED) for “Point Merge”, an innovative technique developed by the EUROCONTROL Experimental Centre, and designed to improve and harmonise arrival operations in terminal airspace with a pan-European perspective.

### 1.2 Document lifecycle

The document is based on EUROCAE WG53 guidance (Ref [42])<sup>1</sup> and is intended to be used as “the basis for assessing and establishing operational, safety, performance and interoperability requirements for the related CNS/ATM system”. For this purpose, it identifies the (Air Traffic) Services and their intended operational environments as well as the operational performance expectations, functions, and selected technologies.

This document is expected to be updated when necessary, according to new developments and lessons learnt from validation, trials or operations. Doing so will enable the capture of requirements that have been derived and/or validated as being necessary for the considered operational service, along with performance and operability justifications.

A first version of the document (v1.0) was released in April 2008, supported by results from generic assessments of Point Merge application in approach airspace (including real time human-in-the-loop prototyping sessions, and complemented by fast time simulations).

The present version (v2.0) is an update issued following further validation activities, including a series of local/specific real-time simulations addressing the short-term implementation of Point Merge in three candidate terminal areas (Oslo, Dublin and Rome), as well as an initial safety assessment. It also incorporates the results from a study to investigate the applicability, benefits and limitations of Point Merge for ACC arrival sectors.

### 1.3 Intended audience

This document is intended for the following audience:

- Air Navigation Service Providers (ANSPs) and other stakeholders having an interest in improved arrival procedures (involving continuous descents and/or P-RNAV), or ANSPs considering Point Merge implementation in the short term. In this context, the present document should serve as a reference.
- Stakeholders that are involved in the development of medium term concepts in the frame of the Single European Sky ATM Research programme (SESAR). In this context, the present document should be considered as an input describing a basis for further operational improvements.

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<sup>1</sup> Although [ED78A] is primarily intended for operational services based on data communications, its guidelines could be adapted to the description of operational services relying on voice communications.

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## 1.4 Document structure

### Document body

Section 1 (the present section) provides general information about the document, including its purpose, lifecycle and intended audience.

Section 2 details the scope and objective of the considered operational service, as well as its maturity and the status of related assessment activities.

Section 3 defines the considered operational context in terms of airspace and control phases, as well as air traffic control tasks.

Section 4 gives an overview of the current procedures (vectoring and P-RNAV).

Section 5 describes the new procedure, including route structure, operating method, main design options and essential requirements.

Section 6 provides an analysis of differences between Point Merge and current operating methods.

### Annexes

Section 7 details the operating method associated with the new procedure, considering the normal mode (with main and alternate flows) and abnormal modes.

Section 8 describes the possible options in the design of the route structure, as well as their expected impact on feasibility, applicability and performance aspects.

Section 9 provides examples of the application of the new procedure to various contexts of operations.

Section 10 provides examples of controller's screens and a sample chart for a Point Merge procedure in Approach.

Section 11 gives more insight on the Point Merge procedure from the cockpit standpoint.

Section 12 details additional guidelines, with respect to Airborne Collision Avoidance System (ACAS), traffic presentation, terrain clearance and transition altitude.

Section 13 describes the environment in terms of airspace, traffic, technical characteristics, as well as actors.

Section 14 gives an insight on the links with future concept elements.

Section 15 details how Point Merge relates to SESAR.

Section 16 gives general definitions of terms and lists acronyms and reference documents.

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## 2. Scope, objective and maturity

### 2.1 Scope and objective

The operational service detailed in this document relates to the arrival phase of flight (cf. §3.1, Airspace and control phases). It relies on a systemised method for merging arrival flows with closed loop instructions, denoted “Point Merge”.

Point Merge was designed to enable extensive use of lateral guidance by the flight management system (FMS), even under high traffic load, and also features a built-in continuous descent (CDA). It was derived from an earlier study on airborne spacing “sequencing and merging” conducted at the EUROCONTROL Experimental Centre (Ref [17]).

#### A short-term application...

Point Merge is supported by existing technology, i.e. the use of a dedicated RNAV route structure, and formally corresponds to a P-RNAV application usable in high, medium or low density terminal airspace. It is therefore expected to be deployable from the 2012 timeframe and fits in SESAR early operational improvements (IP1 – “Implementation Package 1”, see §15). It also fits in:

- The early steps of the Airspace Strategy (Ref [7])<sup>2</sup> and Navigation Strategy (Ref [8])<sup>3</sup> for the ECAC area;
- The European Joint Industry CDA Action Plan (Ref [15]).

#### ...with the potential for future improvements

The operational service defined in this document is also expected to form a sound foundation to support future developments towards the SESAR target concept. It thus fits in the SESAR roadmap as a building block for future operational improvements (IP2 and IP3 – “Implementation Packages 2 and 3”, see §14 and §15). Among these are:

- Advanced continuous descent approaches (towards 3D);
- Improvement of spacing accuracy with adapted ground tools;
- Use of pre-defined RNAV routes (ultimately allocation thereof) with advanced ground support/decision tools;
- Airborne Separation Assistance Systems – sequencing and merging (ASAS S&M);
- Trajectory-based operations (towards 4D trajectory management, including adherence to an agreed or constrained time of arrival).

#### Notes:

1. The application of RNAV concepts for the management of departures in terminal airspace is outside the scope of the present document.
2. Whilst Point Merge is enabling continuous descents, due regard should also be given to departures climb out performances (see §9.1.2.6).

## 2.2 Status of assessment activities and support to implementation

### 2.2.1 Generic validation

The Point Merge procedure has already been studied and found feasible and beneficial in various ‘generic’ environments in Approach, notably with two, three or four entry points; one or two runways; and different TMA sizes (Ref [19], [20], [21], [22]).

Under this generic validation thread, activities carried out between end 2005 and 2008 include ground prototyping sessions using real-time human-in-the-loop simulations, flight deck simulations, and model-based simulations. A summary of assessment results can be found in §9.1.3.

<sup>2</sup> Strategic stream 1 - strategic step 3 “Increasing use of RNAV SIDs and STARs”.

<sup>3</sup> Strategic step 2 “Application of Precision RNAV in Terminal & En Route Airspace for ATS routes, arrival and departure procedures”.

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Validation has shown in particular that, in addition to enabling extensive P-RNAV application, the systematisation of continuous descents from typically FL100 would be possible with the new procedure (Ref [19],[21]), subject to local constraints. In addition, specific configurations may enable continuous descents from closer to the cruise level (see §2.1, 8.2, 14.2 and Ref [22]).

A ‘Point Merge Procedure Design and Coding Assessment’ has also been conducted in 2007 (Ref [24]), involving a verification of conformance of the Point Merge procedure to existing international standards (e.g. Ref [10]), and identification of areas where there may be issues. Point Merge has been deemed “very well suited to RNAV operations”, and “present very few obvious critical issues” (special attention areas when designing and charting the procedure, or coordination with navigation database providers and FMS datahouses).

An initial safety assessment has been conducted (including a safety workshop with candidate ANSPs, and an initial FHA/PSSA) and would have to be formalized through the production of safety requirements and related evidence to support the development of preliminary safety case.

Finally, regarding the application of Point Merge to extended TMA (i.e. before the IAF, as described in §9.2), a joint study has been conducted with DSN (the French air navigation service provider) in 2009 with more than 40 controllers exposed (cf. §9.2.3). This study showed that Point Merge is easy to learn and reduces both workload and communications. Point Merge has substantial potential to improve safety and increase capacity without increasing distance flown. Further studies would be necessary to confirm the applicability of Point Merge on other types of sectors and with full scale arrival manager operations.

### 2.2.2 Implementation support

The EUROCONTROL support to Point Merge implementation started in 2007 with three candidate ANSPs:

- AVINOR (Oslo Gardermoen, planned implementation date: 2011);
- IAA (Dublin, considered implementation date: 2012);
- ENAV (implementation considered in Rome Fiumicino).

This activity encompassed:

- support to Point Merge procedure design;
- a large scale assessment carried out successfully for Oslo in 2008/2009 (Ref [37], [38]) through fast time simulations at the EUROCONTROL Central European Research, Development and Simulation Centre (CRDS), and controllers real time simulations at the EUROCONTROL Experimental Centre (EEC);
- an initial real-time simulation conducted at the EEC for Dublin in 2007 (Ref [39]), followed by a second simulation in 2010 looking at the expected Dublin TMA 2012 environment including Point Merge and CDAs (Ref [40]);
- an initial real-time simulation conducted at the Rome ACC in 2008 and focusing on the TMA(Ref [41]), followed by larger scale simulations involving ACC sectors and arrival manager, conducted at ENAV premises in 2009 (Ref [36]).

#### Notes:

1. More information about Point Merge activities are available from the project web page in the EUROCONTROL web site (Ref [18]), and from the Point Merge page in the EUROCONTROL Navigation Domain sub-site ([http://www.ecacnav.com/PRNAV/Point\\_Merge](http://www.ecacnav.com/PRNAV/Point_Merge)).
2. Although some of the examples provided below for illustration purposes may relate to the specific context of Approach airspace, the new procedure is described in §5 and §7 as ‘generically’ as possible.

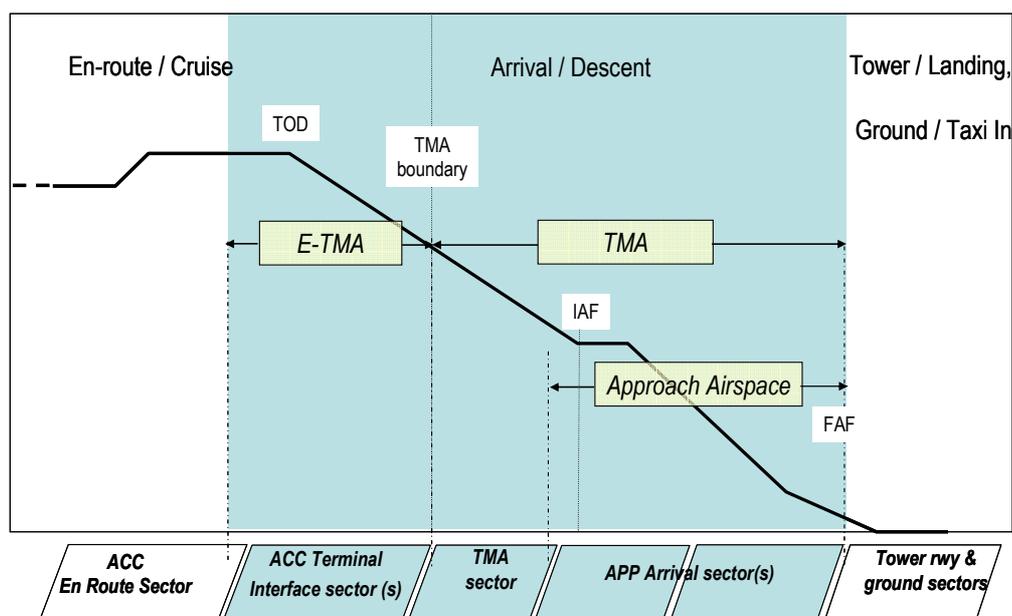
### 3. Operational context

#### 3.1 Airspace and control phases

The procedures described in this document are concerned with the arrival phase of flights, typically starting when aircraft leave their cruise level in En-Route – having reached their Top of Descent (TOD), and ending when aircraft reach the FAF or are transferred to the Tower. This phase mainly relates to Terminal Airspace<sup>4</sup> and includes the Terminal Manoeuvring Area (TMA), and Approach control. Although it is a rather specific notion, an Extended Terminal Area (E-TMA) may also be introduced to handle high-density managed airspace dealing with traffic inbound to one or several major airport(s). E-TMA could be considered as a transition between En-Route and TMA sectors, generally corresponding to delegated airspace from En-Route and covering the control phase of flights that are already in descent – or about to start descent, leaving the En-Route network – but have not entered the TMA yet.

Consequently, for the purpose of this document, as depicted in Figure 3-1 below, and although the TMA formally encompasses the Approach, we will consider for arrivals in terminal airspace the succession of E-TMA, TMA – and inside TMA, the Approach:

- E-TMA/TMA, including ACC terminal interface sector(s) and/or possibly TMA sector(s), typically between the TOD and the IAF;
- Approach airspace / Approach control phase, corresponding to Approach (APP) arrival sectors, typically between the IAF and the FAF or transfer to the Tower.



**Figure 3-1. Control phases and sectors for the arrival phase of flight**

Note: in practice, depending on the local organisation:

- TMA sector controllers, when TMA sectors exist, may actually be either co-located with ACC terminal sector controllers, i.e. within an ACC, or co-located with APP sector controllers;
- The IAF, and associated holding stacks when defined, may be within the area of responsibility of a TMA sector, or (as depicted above) of an APP sector;
- E-TMA, when defined/applicable, corresponds to ‘ACC Terminal Interface’ sectors depicted above.

<sup>4</sup> Defined as “a generic term describing airspace surrounding an airport within which air traffic services are provided. It encompasses all other various terminology currently used throughout ECAC (i.e.: TMA, CTA, CTR, SRZ and ATZ airspace classifications) or any other nomenclature used to describe the airspace around an airport” (Ref [9]).

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### 3.2 Air traffic control tasks

In terminal airspace, aircraft approaching one or more aerodrome(s) from surrounding sectors typically follow a number of STARs providing the transition from the En-Route structure, and are progressively merged into a single flow for each active landing runway.

In this context, the goal to enable a safe, expeditious and orderly flow of air traffic translates into three main arrival tasks for the controllers (Ref [11], Annex D):

- Separate arrivals from other arrivals;
- Separate arrivals from departures<sup>5</sup>;
- Integrate arrivals safely and efficiently into a landing sequence to each runway.

Air traffic control (ATC) tasks also include:

- Separate arrivals and departures from terrain/obstacles (subject to the operational context, according to the ICAO regulation governing responsibility for terrain clearance – see §12.3), and
- Prevent unauthorized entry into segregated areas.

In E-TMA, ATC tasks include the following specific arrival tasks:

- Separate arrivals from over flights;
- Integrate arrivals safely and efficiently into intermediate sequence(s).

#### Notes:

1. ATC tasks in TMA may also encompass the separation between arrivals and overflights (e.g. low performance aircraft).
2. The integration of departures at terminal area exit points is outside the scope of the present document.

### 3.3 Focus on the integration of arrivals

#### 3.3.1 Operational objectives: convergence versus spacing

This document is specifically concerned with the ATC tasks: “Integrate arrivals safely and efficiently into a landing sequence to each runway” as primary focus, and “Integrate arrivals safely and efficiently into intermediate sequence(s)” as secondary focus.

Formally, a “safe and efficient” arrival sequence refers to the provision of a throughput as close as possible to the available/required runway (or downstream airspace) capacity<sup>6</sup>, while conforming to applicable separation requirements. This in turn corresponds to two main objectives that may appear as contradictory (Figure 3-2):

- Ensure (progressive) convergence, ultimately towards the runway, in all dimensions (lateral, vertical, longitudinal);
- Ensure spacing (longitudinally) for metering purposes, or for separation (in at least one dimension: laterally, vertically, or longitudinally) – ultimately towards the required runway separation.

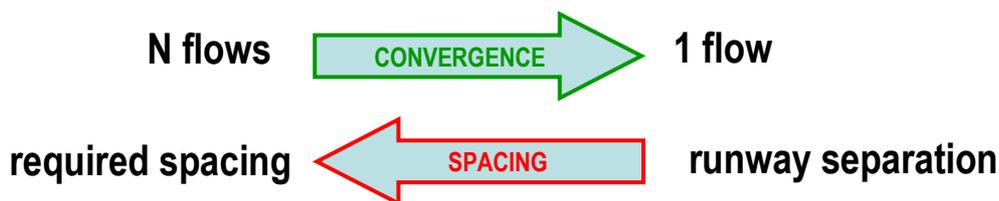


Figure 3-2. Convergence versus separation objectives

<sup>5</sup> The separation of arrivals and departures is generally facilitated by strategic de-confliction of SIDs and STARs.

<sup>6</sup> At least in high traffic conditions; this is often referred to as maintenance of “runway pressure”, i.e. avoiding unnecessary gaps at the runway threshold in so far as possible.

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These objectives are realised through the achievement of both:

- An appropriate sequence order (objective: **sequencing**), driven by the need to optimise runway capacity usage (according to e.g. wake turbulence categories)<sup>7</sup>;
- An appropriate inter-aircraft spacing, driven, again, by the need to optimise runway capacity usage (maintaining a sufficient ‘pressure’ to the runway regardless of the sequence order) and by the need to:
  - Ensure safe distances between flights tactically (objective: **separation**);
  - Anticipate, in so far as possible, on downstream capacity constraints (objective: **metering**).

Sequencing, separation and metering objectives are further illustrated in §16.1.

Notes:

1. The need for ‘metering’ – also often referred to as ‘pre-regulation’ or ‘pre-sequencing’, is linked to the backwards propagation of downstream capacity constraints along the sequence of aircraft that are virtually “queuing” to land on the runway: during traffic peaks, demand may temporarily exceed the available runway and TMA capacity; in order to avoid systematic recourse to holding, metering measures can then be applied before reaching the TMA boundary.

2. Metering may be applied in a static manner e.g. through Letters of Agreement (LoAs) including inter-aircraft spacing requirements and/or speed restrictions. It may also be applied dynamically at the flow level e.g. through global speed reductions tactically instructed by ATC with no reference to a sequence order, or at the level of individual aircraft with reference to a sequence order. The latter case involves a lower granularity than flow metering, and requires the sequence to be stable enough. With the support of an adequate tool such as an Arrival Manager (AMAN), dynamic/individual metering constraints can be anticipated, managed and co-ordinated more accurately. Such anticipation, although it introduces early constraints management in upstream sectors, reduces the need for holding and is globally beneficial in terms of overall ATC workload and flight efficiency.

### 3.3.2 Intermediate and final sequences

Schematically, the integration of arrival flows involves a progressive convergence along the lateral, vertical and longitudinal/time dimensions, ultimately to the runway. Due to this progressive nature, intermediate sequences must generally be built, and traffic flows synchronised<sup>8</sup> in view of achieving the global sequence towards the runway. Therefore, the integration of arrivals may be broken down into the management of a succession of intermediate sequences to intermediate merging points, eventually leading to the final sequence to the runway.

Managing intermediate arrival sequences, typically in E-TMA/TMA sectors, aims at achieving the following operational objectives:

- Sequencing (ordering) of flights,
- Separation, and
- Metering (e.g. towards an IAF, or a metering point before an IAF).

Managing the final landing sequence (typically in the Approach) involves the following objectives:

- Final sequencing (ordering) of flights,
- Separation towards the runway.

<sup>7</sup> Indeed, the final sequence order at the runway has an impact on required inter-aircraft spacing (according to wake turbulence categories of leading and trailing aircraft).

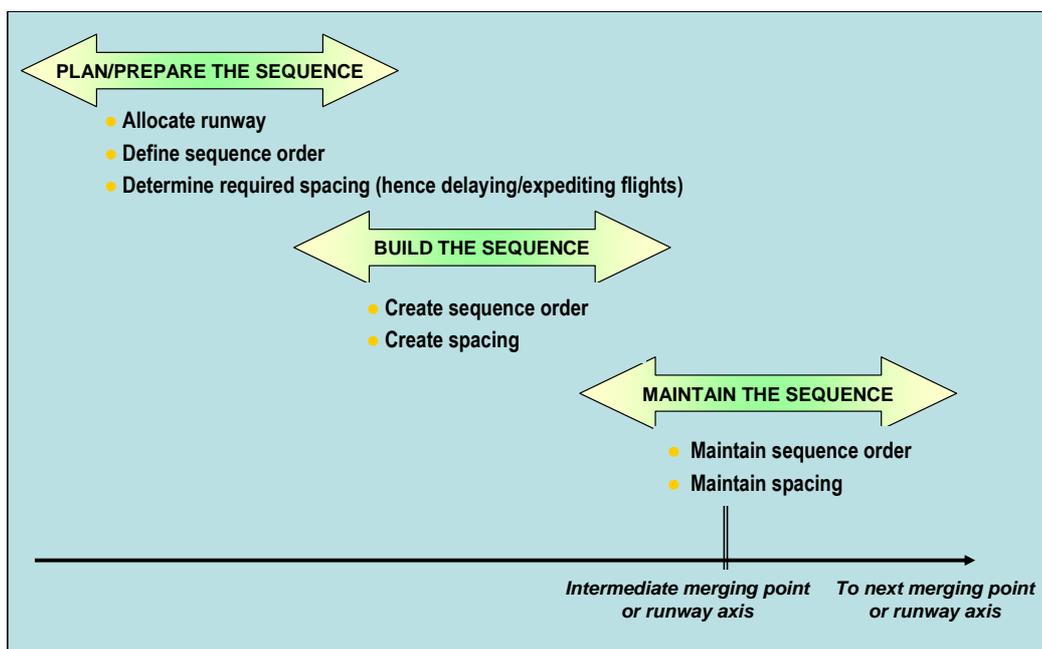
<sup>8</sup> The SESAR CONOPS (Ref[48]) refers to “queue management”, encompassing separation and synchronisation aspects – with no clear boundary between these two processes, but does not use the term ‘traffic synchronisation’ anymore. Throughout this document, the term ‘metering’ is used instead of ‘synchronisation’.

### 3.3.3 Phases in sequence management

The management of each sequence (be it intermediate or final) can also be described according to the following phases, each retaining all operational objectives depicted above i.e. sequencing, separation, metering:

1. Planning/Preparing the sequence: landing runway allocation, sequence order and appropriate spacing;
2. Building the sequence: creation of order and appropriate inter-aircraft spacing;
3. Maintaining the sequence: maintenance of sequence order, and maintenance/refinement of inter-aircraft spacing.

Because the planned sequence can evolve, there may be overlaps between these phases, as shown in the diagram below.



**Figure 3-3. Phases in the management of intermediate or final sequences**

### 3.3.4 The need for lateral path stretching or shortening

For the purpose of integrating arrival flows, the building and maintenance of a sequence require the ability to expedite or delay aircraft in order to achieve longitudinal spacing. When traffic demand rises, and/or depending on traffic presentation, speed adjustments may not be sufficient and path shortening/path stretching may become necessary. It is therefore essential in dense terminal airspace, that any arrival integration technique provides enough flexibility to enable sufficient path stretching/shortening capability, to the extent of airspace capacity.

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## 4. Current procedures

### 4.1 Conventional operating methods

The progressive merging of arrival flows into a runway sequence is often performed in current day operations through the use of open-loop vectoring when path stretching/shortening is required. In case of high traffic, air traffic controllers typically issue a large number of heading, speed and FL/Altitude tactical instructions. This method is highly flexible; however it results in high workload both for flight crews and controllers<sup>9</sup>, and in an intensive use of the R/T. Indeed, it generally requires numerous actions to deviate aircraft from their most direct route for path stretching – and later put them back towards a waypoint (e.g. the IAF) or the runway axis for integration.

Additionally, it is not efficient for the flight crew or the operation of the aircraft (especially as regards vertical profiles): with open-loop vectors, flight crews' situation awareness is poor, while some FMS functions become unavailable (such as maintaining the 'distance to go'). The use of open-loop vectors also causes inefficiency in the ground system: ground-based tools involving trajectory prediction (e.g. conflict detection tools, AMAN) cannot be updated appropriately since the time when/location where aircraft will resume their normal navigation is not known. In case an AMAN is used, the sequence manager may not be fully aware of other controllers' intentions when they are vectoring aircraft.

In E-TMA/TMA sectors, where a route structure is generally defined, controllers give speed and/or heading/direct-to instructions as needed to separate and/or meter (pre-regulate) arrivals towards TMA entry points or IAFs.

Holding stacks may be used, subject to local practices, when the TMA capacity is exceeded at peak times, or more systematically to maintain the 'pressure' at the runway.

In the Approach phase (i.e. generally after passing the IAF), in the absence of a route structure, controllers further vector the aircraft to fine tune the arrival sequence and integrate traffic flows from different IAFs to the runway axis. In dense and/or complex environments, controllers tend to follow a strategy giving themselves more time and margins to implement and fine tuning the sequence. This often results in aircraft flying low and slow. In addition, the lack of a 2D structure generally leads to a tactical management of conflicts with other flows, inducing intermediate level offs.

### 4.2 Advanced procedures and tools

#### 4.2.1 RNAV arrival procedures

Today, Precision Area Navigation (P-RNAV, see §16.1) arrival procedures have been defined in the vicinity of some European airports, aiming at airspace capacity, workload, efficiency, predictability and/or environment-related benefits. These procedures have been designed with the goal of replacing open-loop vectors in Approach for arrivals, and allowing revisiting associated working methods. However, it shall be remarked that maximum benefits in all of these areas cannot generally be achieved through a single procedure, and trade-offs may have to be considered, or focus put on certain Key Performance Areas (KPAs), according to local constraints.

For instance, RNAV procedures providing the most direct routes to final have been defined e.g. in Stockholm to support flight-efficient descents (see 'continuous descents' below). However these procedures are not meant to provide capacity and are generally used only in low traffic density.

On the other hand, in order to integrate arrival flows in dense traffic situations, 'trombone' shaped RNAV transitions have been in use in München or Frankfurt for a significant period of time now. These procedures roughly replicate typical vectoring patterns. They include a set of regularly spaced waypoints defined in the downwind and final approach segments<sup>10</sup>, aiming at supporting path stretching/shortening through route changes, while normally keeping the aircraft on lateral navigation.

<sup>9</sup> It shall also be kept in mind that the responsibility for terrain clearance passes from the flight crew to the ground when vectoring is initiated.

<sup>10</sup> Such waypoints are even defined in upwind segments sometimes (e.g. BETOS 08 or NAPSA 26 RNAV transitions in München).

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This design has proved an effective way of systemising the traffic flows to the runways. It results in a significant path stretching capability to the extent of available airspace. However, such RNAV procedures are generally fully applied only under low to medium traffic loads; according to Ref [10], §10.2.2: *“The main disadvantage of RNAV procedures is that they reduce the flexibility that radar vectoring affords the controller and experience has shown that, without the help of a very advanced arrival manager, controllers tend to revert to radar vectoring during the peak periods”*. Further, according to TMA2010+ (Ref [16]), *“In recent times, Precision Area Navigation (P-RNAV) applications in the terminal area have not realised all the anticipated benefits of reduced cost, improved environment and increased capacity. PRNAV procedures can be integrated with conventional procedures and can bring environmental, financial and operational benefits in light and medium traffic loads. However, at high traffic loads, the controllers inevitably revert to radar vectoring in order to maximise capacity.”*

The reasons for these limitations are that:

- The discontinuity of lateral alterations of trajectories through pre-defined tactical waypoints does not enable controllers to easily 'fine-tune' spacing between successive aircraft. This is especially the case during periods of high traffic load, where it is common practice for controllers to use radar vectoring techniques between downwind and final to ensure runway throughput is optimised by reducing spacing between aircraft to the extent possible<sup>11</sup>.
- Route changes with a large set of available waypoints may require lengthy manipulation in the cockpit, possibly resulting in a long reaction time when a route change is instructed, and risk of confusion/errors.

Finally, whilst “trombone” shaped RNAV transitions may simultaneously offer a large path stretching capability and allow maintaining runway pressure and offer high flexibility in “filling the gaps” in the sequence (e.g. in case of go-around), such flexibility requires anticipating on path shortening, hence early descents, and non optimal vertical profiles. Again, the notion of a trade-off between some KPAs, as opposed to maximum benefits in every KPAs, has to be considered.

#### 4.2.2 Continuous descent

Regarding vertical profiles, currently Continuous Descent Approach procedures (CDA, see §16.1 and Ref [14]) are used in some European TMAs and consist in:

- Either the use of dedicated RNAV procedures (“STAR-based CDA”) – generally only possible in low traffic density situations, e.g. at night;
- Or the tactical provision of distance to go (DTG) information by ATC in a vectoring environment (“Radar-based CDA”), often from lower altitudes e.g. from about 6000ft in London Heathrow, with partial benefits<sup>12</sup>.

#### 4.2.3 Arrival management

In a number of busy European TMAs, Arrival Management tools (AMAN) have been deployed to support the planning and building of the arrival sequence(s). Due to uncertainties on aircraft trajectories (including the case of short haul flights), and sometimes airspace boundaries issues, these tools are offering at best an operational horizon in the range of 35 minutes before touchdown. However in some of the busiest TMAs (e.g. Paris or Frankfurt), the use of an AMAN has proven useful to support the sequence optimisation and implementation, including traffic pre-sequencing (metering towards the IAFs) through coordination between the ACC and the Approach.

<sup>11</sup> Ref [9], Part C, §5.2.1: “[...] Closed STARs can be designed and published in a manner that anticipates alternative routeing to be given by ATC on a tactical basis. Whilst tactical routeing instructions to ‘close’ an Open STAR are necessary to align the aircraft with the final approach track, ‘tactical’ way points may be included in a Closed STAR so as to permit ATC to alter the routeing of an aircraft e.g. to provide a short cut. (These tactical instructions may be given in the form of instructions ‘direct to a way-point’ or Radar Vectors).”

<sup>12</sup> Ref [14]: *“The use of tactical DTG by means of ATC advisories will allow pilots to achieve a CDA or partial CDA even in busy periods. However the noise performance for individual flights may not be as good as a pure optimised P-RNAV CDA procedure - i.e., without vectoring”*.

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Notes:

1. There is obviously a trade-off between flexibility and predictability regarding procedures for arrival flows integration. Current vectoring procedures offer high flexibility, but on the other hand, predictability is low and the corresponding tasks are quite demanding for air traffic controllers and for the aircrew.
2. There is another trade-off between the individual flight efficiency (especially regarding the possibility to fly the best individual vertical profile involving e.g. a continuous descent) and overall system capacity.
3. With open-loop vectors, there are some overlaps in task allocation between controllers regarding the sequence building and maintenance. Depending on local practices, controllers in successive Terminal and Approach sectors can all make decisions on sequence order. Approach controllers work in a highly co-operative manner to build the sequence order and achieve the proper spacing on final. This is done in a progressive way, and plans can change quite late: airspace permitting, there may remain some freedom to amend the sequence order until aircraft turn to join the runway axis.

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## 5. New procedure

This section describes the new procedure through:

- an overview of its principles and constituents i.e. route structure and operating method (§5.1);
- the main procedure design options and an analysis of their possible combinations (§5.2).
- the detailing of expected benefits, anticipated constraints and human factors (§5.3);
- the identification of essential requirements and recommendations, including enablers (§5.4);

### 5.1 Overview

#### 5.1.1 Guiding rules

In view of improving and harmonising arrival operations in terminal airspace, while adhering to the scope and objectives as defined in §1 and §2 above, the following rules will apply to the new procedure:

4. Aiming at short term deployment, the operational impact of change management should be minimised. Therefore, there will be no new principles of operations compared to current/standard ATC operations. Especially, no change with respect to the ATC goal, which will remain to enable a safe, expeditious and orderly flow of air traffic. It is also expected that there will not be any regulatory issues, in particular regarding ICAO PANS-ATM (Doc 4444, Ref [2]). Separation minima – and spacing – will still be based on distance<sup>13</sup>.
5. Focusing on arrivals, design guidelines for terminal airspace will be applicable (Ref [9]). In addition, being based on P-RNAV (see §5.4.10), design guidelines for P-RNAV procedures will be applicable (Ref [10], [11]).
6. In order to address safety and capacity issues, the new procedure should reduce the need for controller tactical intervention<sup>14</sup>, by keeping aircraft on lateral navigation, even at high traffic loads and rely on simple closed loop clearances/instructions. Open-loop radar vectors should only be used to recover from unexpected situations.
7. The new procedure shall be flexible enough to maintain capacity/throughput, including during periods of high traffic load. It shall therefore provide a built-in capability of delaying or expediting aircraft (through path stretching/shortening) in a more flexible manner than current P-RNAV applications in TMA, based on e.g. pre-defined route changes).
8. The procedure should nevertheless also provide some form of lateral predictability, to support an improved efficiency of vertical profiles – and ultimately be compatible with, or pave the way towards Advanced Continuous Descent Approach (A-CDA) concepts.
9. A key principle highlighted in Ref [10] for RNAV procedures is to keep things simple<sup>15</sup>. The new procedure shall provide the controllers with a structured and intuitive way of building and maintaining the sequence, with, in so far as possible, no requirement for new tools<sup>16</sup>.
10. Finally, the procedure should also fit in with well-established air and ground practices and related constraints. In particular, from a cockpit perspective, ‘head-down’ time should be minimised when aircraft is below FL100, considered as a critical phase of flight.

<sup>13</sup> Although the new procedure is expected to be compatible with time-based spacing/separation.

<sup>14</sup> In line with the SESAR CONOPS (Ref [48]).

<sup>15</sup> Ref. [10], §1.4.1 “An important aspect of RNAV procedure design methodology is the need to keep things simple. Complex solutions are difficult to validate, are open to misinterpretation and are prone to error. The designer should always strive to develop the simplest procedure and, in so doing, focus on waypoint to waypoint flying.”

<sup>16</sup> New tools may be considered in future steps, or as part of the 2012/2015 environment but may not be required in a first stage, i.e. in the context of the present procedure.

### 5.1.2 Constituents

Following the above guiding rules led to revisit the integration of arrival flows by adopting a “fresh” standpoint, based on an analogy with pre-sequencing in extended TMA, in which merging is performed on a point<sup>17</sup>. The new procedure, called “**Point Merge**”, is a P-RNAV application based on two constituents intrinsically linked:

- A specific route structure with an inherent converging geometry and an embedded path stretching capability;
- An associated systemised operating method enabling extensive use of RNAV with a built-in continuous descent.

### 5.1.3 Route structure

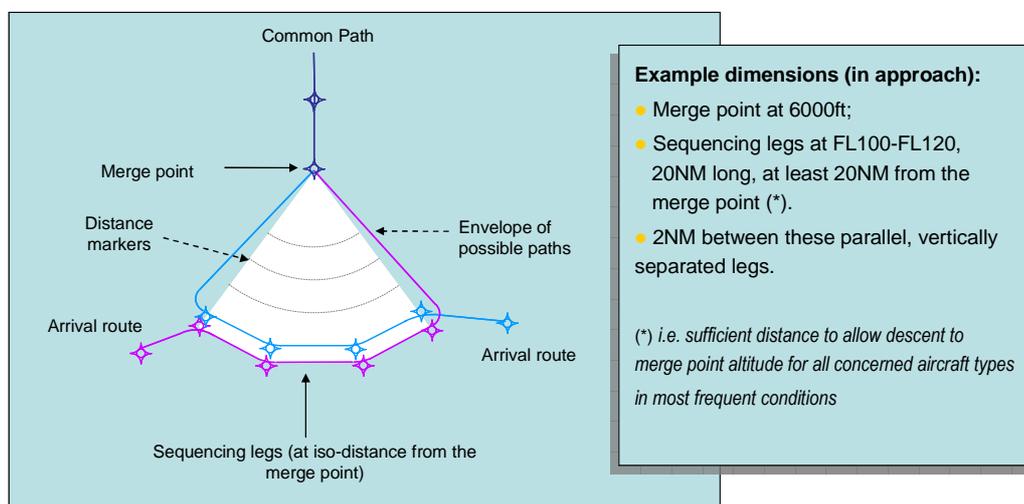
The route structure supporting Point Merge is denoted “**Point Merge System**” (PMS). A PMS may be defined as an RNAV STAR, transition or initial approach procedure, or a portion thereof, and is characterised by the following features:

- A single point – denoted ‘**merge point**’, is used for traffic integration;
- Pre-defined legs – denoted ‘**sequencing legs**’, **isodistant and equidistant from the merge point**, are dedicated to path stretching/shortening<sup>18</sup> for each inbound flow. These legs shall be separated by design vertically, laterally or both.

“Isodistant” means that the distance to the merge point shall remain the same all along a given leg. Strictly speaking, this would be achieved with an arc centred on the merge point.

“Equidistant” means that distinct legs shall be designed at the same distance from the merge point.

In practice, PMS design may (and generally will) involve approximations in at least one of these two design requirements<sup>19</sup>, while still adequately supporting the operating method. For instance, sequencing legs may be segmented to approximate iso-distance, and a lateral distance may be introduced between two parallel sequencing legs, resulting in approximate equidistance.



**Figure 5-1. Example Point Merge route structure**

<sup>17</sup> In contrast, current P-RNAV procedures defined for high density operations in terminal airspace often replicate pre-existing or typical vectoring patterns, merging to an axis.

<sup>18</sup> Whether the notion of both path stretching and shortening may apply here could be debatable. It depends on the chosen ‘reference’ path i.e. the shortest one (direct route to the merge point from the first point of the leg), an ‘average’ one (using only a part of the leg) or even the longest one (including the full length of the sequencing leg). Nevertheless even in case the chosen reference path is the shortest one in the procedure, further path shortening may still be possible through a direct to the merge point prior to leg entry – when relevant, and local conditions permitting.

<sup>19</sup> Arising from the need for a simple and intuitive operating method (cf. §5.1.4)

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Considering a simple configuration with two inbound flows, Figure 5-1 above provides a typical example of a Point Merge system with two sequencing legs that are:

- Parallel (approximating the equidistance requirement with e.g. 2nm lateral distance), of opposite directions and vertically separated;
- Segmented, forming quasi-arcs centred on the merge point (approximating the iso-distance requirement).

The resulting envelope of possible paths towards the merge point is contained in a “triangle-shaped” area.

There are actually many other possible PMS design options, as depicted in §5.2 and §8. However the single merge point and iso-distance/equidistance property of sequencing legs to the merge point are key and invariant aspects of the procedure.

Notes:

1. An equidistance approximation (in case of e.g. parallel legs) results in a ‘constant shift’ of distance between the legs, in turn requiring more accuracy in order to account for that shift when issuing the direct-to instruction; whereas an iso-distance approximation results in a ‘variable shift’ along the legs, according to their shape, which may induce, if too large, a less accurate inter-aircraft spacing.
2. In addition to the merge point and sequencing legs, a PMS is generally expected to include:
  - a. an initial segment feeding each sequencing leg, starting at a defined PMS entry point (e.g. IAF) and ending at the first point of the sequencing leg,
  - b. a ‘sequencing leg run-off’ route segment joining the end of each sequencing leg and the merge point (see §5.1.4 below), and
  - c. a final segment forming a common path, starting at the merge point and ending at a defined PMS exit point (e.g. FAF).
3. Sequencing legs have a pre-defined maximum length, which corresponds to the maximum path stretching capability of the PMS. The nominal path stretching capability used in a PMS should be smaller, leaving sufficient margins to cater for non-nominal conditions by using up to the full length of the legs if required (see §12.2).
4. The active FMS route shall include the full length of the sequencing leg, as well as the subsequent leg run-off segment closing the procedure towards the merge point. This should also form the basis for the route used in case of radio failure (see §7.4.6).

**5.1.4 Operating method**

The Point Merge operating method aims at integrating inbound flows, using a PMS route structure, and comprises two main phases:

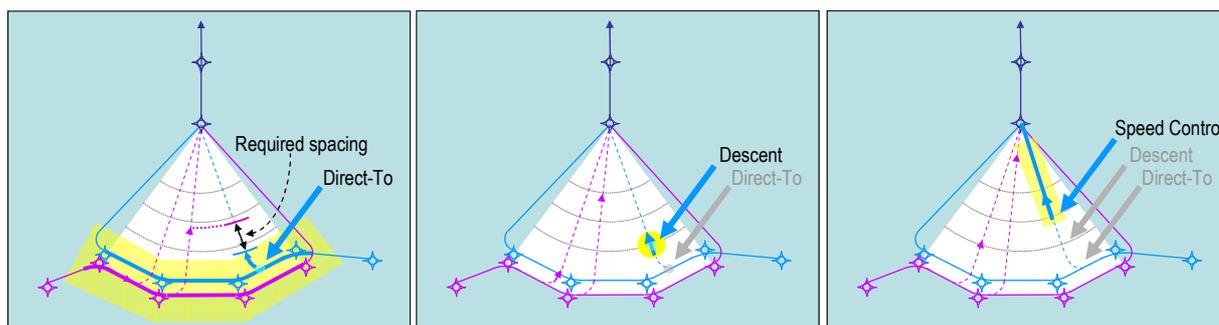
- **Create the spacing** through:
  - path stretching without ATC intervention – by leaving aircraft fly along the sequencing leg, followed by
  - a “direct-to” instruction to the merge point, issued when the appropriate spacing is reached with the preceding aircraft in the sequence;
- **Maintain the spacing** through speed control after leaving the legs.

The normal procedure only involves one ATC lateral intervention i.e. the direct-to instruction. As this is a closed loop intervention, aircraft remain under lateral guidance by the FMS all along the procedure. This “direct-to” instruction is key to the operation of Point Merge as it creates both the sequence order and the initial longitudinal inter-aircraft spacing in the sequence. This property makes it also pivotal when considering how Point Merge relates to phases in sequence management (see §5.2).

Nevertheless, alternate procedures in the frame of Point Merge may involve the use of open-loop vectors e.g. for non equipped aircraft or to deal with unexpected events (see §7.2 and §7.3).

The normal procedure also only involves one ATC vertical intervention i.e. a **descent** clearance that may be given after the direct-to, when clear of traffic on the other leg(s). Subject to design options, this may happen at different stages in the procedure. The descent profile can be optimised accordingly, at least from the sequencing legs altitude/level, in the form of a **Continuous Descent Approach (CDA)** – as the distance to go is known by the FMS<sup>20</sup>.

Figure 5-2 below shows the main steps in the Point Merge operating method (the detailed operating method is provided in §7).



**Figure 5-2. Main steps in Point Merge operating method**

Thanks to the iso/equidistance property in the route structure, during the path stretching phase the controller can easily and intuitively assess the spacing with the preceding aircraft in the sequence (already on course to the merge point), and therefore determine with sufficient accuracy the appropriate moment to issue the ‘direct-to’ instruction, without requiring the support of any new ground tool<sup>21</sup>. Importantly, as stated above, this remains possible even with an approximation in equidistance; it is actually the case in the example shown here, where sequencing legs are designed 2nm apart.

**Note:** Point Merge is normally not thought as an open-ended procedure, as it is by its own principle seeking to decrease tactical ATC interventions and enable extensive use of RNAV<sup>22</sup>. It shall thus be designed as a closed STAR, so that if the aircraft reaches the end of the sequencing leg without receiving a ‘direct-to’ clearance, it turns automatically towards the merge point (using the leg run-off segment as depicted by Figure 5-1 – also see §7.4.1). In the remainder of this document, we will always consider Point Merge as being a closed procedure. Nevertheless, for the sake of readability, subsequent figures will generally not include the ‘closing part’.

<sup>20</sup> Nevertheless, as speed control will remain necessary when descending towards the merge point, this descent cannot generally be performed in “idle thrust” conditions, but following a geometrical vertical profile, ensuring the best compromise between the need to optimise the individual vertical profiles and the need to achieve a safe and efficient sequence – even under high traffic loads.

<sup>21</sup> See §5.4.10. Distance markers centred on the merge point may be needed; this not a new tool but a standard feature of current controller working positions.

<sup>22</sup> See §5.1.1. Also, Ref[9] states in Part C §5.2.1: “Whilst the Open Star provides and publishes track guidance (usually) to the down wind position from which the aircraft is tactically guided by ATC to intercept the final approach track, closed STARs provide track guidance to the final approach track whereupon the aircraft usually intercepts the ILS. In theory, the closed STAR suggests that the aircraft can navigate itself along the published route onto the final approach track, without being dependent on ATC for navigational guidance.”

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## 5.2 Main design options and possible combinations

This section identifies the main design options for Point Merge (§5.2.1) and their possible combinations (§5.2.2).

### 5.2.1 Identification of main options

As stated in §5.1.3, the sequencing legs shall be separated in at least one dimension: laterally or vertically. The same dimension may be used all along the legs or a combination of both (e.g. lateral separation in some parts, vertical in others).

Non laterally-separated legs are assumed to be parallel and of same shape (i.e. approximating arcs of circles in the same way), due to iso-distance/equidistance requirements and for the sake of simple/intuitive working method. Vertical separation between legs can be achieved through either levelling off or a constrained descent.

Consequently, the three main options are (Figure 5-3):

- **parallel legs with full overlap**, with level off (constrained descent all along the legs may also be possible);
- **parallel legs with partial overlap**, with constrained descent for the overlapping part (level off is also possible);
- **non parallel legs with no overlap** (dissociated), with an unconstrained descent (however a vertical separation may be required between the ends of legs in case of leg run-off, subject to further safety assessment)<sup>23</sup>.

Note: considering the three steps of the operating method (before, during and after merging), the three main options only apply to the first step (before, i.e. ‘create spacing’ through path stretching along the legs) and do not affect the other two. Indeed, the direct-to instruction has an invariant and pivotal role in Point Merge as it triggers the actual merging of flows. Subsequent spacing maintenance through speed control is also invariant.

Implications regarding vertical profiles:

- **level off**: continuous descents (CDAs) will be possible from the level/altitude of the sequencing legs (when on course to the merge point).
- **descent constrained by the other leg(s)**: aircraft may then follow a ‘gentle descent’ on both legs<sup>24</sup> at least along their first part. Once on course to the merge point, the vertical profile can be adjusted. Uninterrupted CDAs from closer to the cruise level become possible.
- **descent unconstrained by other leg(s)**<sup>25</sup>, only subject to adjustment of the vertical profile when on course to the merge point, assuming the minimum and maximum distances are close enough (i.e. the leg is short enough). CDAs from closer to the cruise level become possible.

Regarding entry conditions, traffic may not be pre-sequenced and in particular not longitudinally separated<sup>26</sup>. In case of level-off, this may be catered for by the use of multiple level(s)/altitude(s) on the leg(s), typically two or three<sup>27</sup>. In order to further facilitate adherence to entry conditions (traffic de-confliction and descent), the controller may tactically send aircraft to intermediate points on the legs. For instance, within a given inbound flow, the controller would alternatively give to some aircraft a direct to the second or third point of the leg.

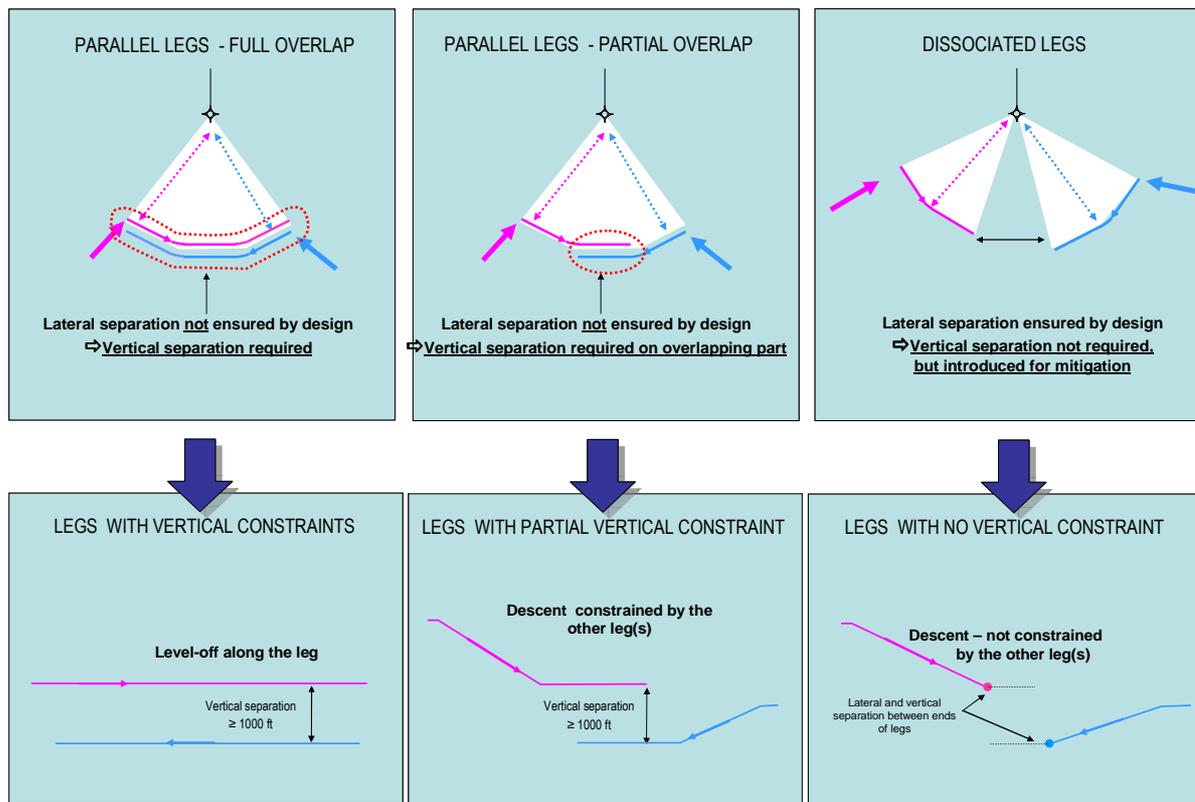
<sup>23</sup> An alternative, or complement, may be a specific protection area to cater for lateral separation.

<sup>24</sup> Actually in case of parallel sequencing legs, it might even be envisaged to design one leg with a level off constraint and the other one with aircraft allowed descending. However such a design choice would obviously result in an inequitable management of arrival flows and make the ATC sequence building tasks more complex due to differences in level/altitude/speed.

<sup>25</sup> Even in that case, vertical profile constraints may exist e.g. in order to make sure the expected range of aircraft types on the considered airport will be able to descend to the merge point’s altitude with the shortest route.

<sup>26</sup> In case of dissociated legs with no level-off, having aircraft in descent, the delivery over several levels will not be possible. With such a design, the traffic entering each leg has to be adequately metered and longitudinally separated.

<sup>27</sup> Using too many flight levels globally in a Point Merge system may raise speed compatibility issues.



**Figure 5-3. Options: lateral and vertical design of sequencing legs**

Note:

1. The use of multiple levels shall not be confused with the use of a spare level (see §6.4 below), as the latter is expected to be used in exceptional cases only, for e.g. recovery from a level bust.
2. There are other design options – of a secondary nature since not related to separation and not impacting the operating method: variations in the geometry and dimensions of Point Merge systems, or the possibility to combine Point Merge systems (Cf. sections 8 and 9).

**5.2.2 Summary of possible combinations**

Table 5-1 below summarises the main options, their possible combinations, as well as their specific advantages or drawbacks, and their impact on the operating method or entry conditions.

Note: a study on potential ACAS nuisance RAs with Point Merge was carried out, focussing on the case of parallel legs with level off (cf. §12.1). This study suggested two types of solutions to limit the occurrence of such nuisance alerts i.e. vertical restrictions ahead of the sequencing leg's entry, or limiting the descent rate in the last 1000ft. Specific studies may be needed in case of different designs; for instance in case of multiple levels per leg, in order to avoid propagating the vertical constraints too far out from the leg entry, the descent rate limitation may be the preferred solution.

Legs lateral design	Legs vertical design	Levels per leg	Entry conditions	Comments
<b>PARALLEL WITH FULL OVERLAP</b>	<b>Level-off</b> along the legs	<b>Single</b>	<ul style="list-style-type: none"> <li>• Longitudinal separation</li> <li>• Stable at defined level prior to entering the leg</li> </ul>	<ul style="list-style-type: none"> <li>- Validated</li> <li>- CDA interrupted along the legs</li> <li>- Less airspace used (laterally) than dissociated legs</li> </ul>
		<b>Multiple</b>	<ul style="list-style-type: none"> <li>• Longitudinal separation on each level</li> <li>• Stable at one of the defined levels</li> </ul>	<ul style="list-style-type: none"> <li>- Validated in one context (E-TMA)</li> <li>- CDA interrupted along the legs</li> <li>- Less stringent entry conditions than single level/altitude</li> </ul>
	<b>Descent</b> along the leg constrained by other leg(s)	<b>N/A</b>	<ul style="list-style-type: none"> <li>• Longitudinal separation</li> <li>• Within a defined/ constraining vertical window</li> </ul>	<ul style="list-style-type: none"> <li>- Not fully mature (may not bring a significant benefit compared to level-off)</li> <li>- CDA not interrupted (but constrained)</li> <li>- More airspace used locally (vertically) than level-off solution, but less airspace (laterally) than dissociated legs</li> </ul>
<b>PARALLEL WITH PARTIAL OVERLAP</b>	See 'PARALLEL legs' for the overlapping part, and 'DISSOCIATED legs' for the non-overlapping part of the legs.			
<b>DISSOCIATED</b>	<b>Level-off</b> along the legs <i>(possibly same levels used)</i>	<b>Single</b>	<ul style="list-style-type: none"> <li>• Longitudinal separation</li> <li>• Stable at defined level</li> </ul>	<ul style="list-style-type: none"> <li>- Partly validated</li> <li>- CDA interrupted along the legs</li> <li>- Not taking benefit of vertical constraint's release</li> </ul>
		<b>Multiple</b>	<ul style="list-style-type: none"> <li>• Longitudinal separation on each level</li> <li>• Stable at one of the defined levels</li> </ul>	<ul style="list-style-type: none"> <li>- Not validated</li> <li>- CDA interrupted along the legs</li> <li>- Less stringent entry conditions</li> </ul>
	<b>Descent</b> along the leg <u>not</u> constrained by other leg(s)	<b>N/A</b>	<ul style="list-style-type: none"> <li>• Longitudinal separation</li> <li>• Within defined vertical window, if any</li> </ul>	<ul style="list-style-type: none"> <li>- Partly validated</li> <li>- CDA not interrupted along the legs</li> <li>- Uses more airspace (vertically) than level-off, and more airspace (laterally) than parallel legs</li> </ul>

**Table 5-1. Main options in Point Merge design and operating method**

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### 5.3 Expected benefits, anticipated constraints and associated human factors

The present section describes the benefits mechanisms, then captures an initial list of benefits, constraints, and human factors related to the new procedure, as anticipated at the time it was first defined. This list shall therefore only be seen as an early snapshot. Building on subsequent validation results, these aspects were further explored, and the list re-visited in a more structured and systematic way as detailed in §6 below.

#### 5.3.1 Benefit mechanisms

High level benefits and constraints mechanisms can be directly inferred from the possible variations in Point Merge route structure design parameters:

- Capacity: linked to the dimensioning of the route structure i.e. the length of sequencing legs (directly related to delay absorption capacity through path stretching), and the distance between the legs and the merge point (considered jointly these two parameters influence the maximum number of aircraft in the system at any given time);
- Fuel efficiency and environmental impact: linked to the distance between the sequencing legs and the merge point, along with the vertical dimensions of the route structure. These parameters relate to the ability to fly continuous descent approaches; in addition, the overall dimensioning of a Point Merge system is directly related to the containment of trajectories dispersion;
- Predictability: reflected by the ratio between the distance from the sequencing legs to the merge point, and the length of legs (the latter represents the maximum uncertainty in actual trajectory flown under nominal conditions).

Enabling the maintenance of FMS lateral navigation, with continuous descents from the legs, even in high traffic density, has the following consequences:

- Level off or less optimum descent along the sequencing legs;
- Path stretching capability and runway pressure not simultaneously maximised<sup>28</sup>.

Subject to local constraints, the flexibility offered in the adjustment of Point Merge design parameters is expected to enable achieving performance trade-offs according to specific operational objectives.

More generally, it shall be kept in mind that maximum benefits in all Key Performance Areas are generally not obtained simultaneously through a single P-RNAV procedure (see §4.2.1). The Point Merge route structure itself actually exhibits direct links with KPAs (Cf. §8.1), and related trade-offs.

#### 5.3.2 Expected benefits

Point Merge inherits from general P-RNAV improvements, and is also expected to bring the following specific benefits:

- Maintain current runway throughput, during longer periods and with high accuracy (i.e. making full use of available runway capacity at main airports during peak periods) with the potential to match future runway capacity increases;
- Maintain, or possibly increase terminal airspace capacity (through a reduction in controller's workload and in radio-telephony channel occupancy);
- Improve flight efficiency and predictability (through extensive RNAV application and use of FMS lateral guidance even in high traffic);
- Minimise the environmental impact – or optimise it in respect of defined target levels (by enabling more systematic implementation of continuous descents and containing 2D footprint);
- Address staffing and qualification (with standardised and streamlined controller working methods);
- Improve safety (through all of the above).

<sup>28</sup> With Point Merge, the former is linked to the length of sequencing legs; the latter to the capability to easily fill gaps in the sequence, linked to the distance from the legs to the merge point (cf. §4.2.1). Given the specific structure of the route (arc of circle), all other things being equal, increasing runway pressure would directly reduce path stretching capability and vice-versa.

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Point Merge is actually expected to enable a trade-off between these individual improvements, accounting for local constraints.

Note: Point Merge aims at optimising the use of airspace for the integration of flows in busy traffic situations, in terms of capacity, predictability and environmental aspects, but also where possible in terms of track miles flown. All other things being equal, it is indeed not expected that Point Merge would result in longer distances or larger time flown than with current procedures.

### 5.3.3 Anticipated constraints

Anticipated constraints include those resulting from the use of RNAV in terminal airspace, and those that are specific to Point Merge.

From an ATC perspective, P-RNAV related issues in terminal airspace include for instance (Ref [11]):

- General:
  - Change management – as for any new technology.
- Procedure design:
  - Need to include ATC service providers and all involved stakeholders, from an early stage, in the design process.
- Enablers:
  - Navigation accuracy-related constraints: database consistency (including content, interpretation, coding), accuracy of input sources to the RNAV system, and RNAV systems standardisation issues;
  - Information on (and display on CWP of) aircraft capability.
- Operating method:
  - Radio procedures (including R/T provisions at ICAO level and designation of RNAV routes) to cover RNAV application in terminal airspace;
  - Potential confusion over responsibility for terrain clearance<sup>29</sup>;
  - Adequate training to handle specific RNAV aspects (e.g. heterogeneous RNAV-flown turns).

In addition, the following constraints could specifically result from the implementation of Point Merge:

- General:
  - Path stretching capability and maintenance of “runway pressure” not simultaneously maximised (including capability to easily fill gaps in the sequence due to e.g. go-around, late direct-to)<sup>30</sup>.
- Procedure design:
  - Applicability to various terminal airspace types due to triangle-shaped route structure – taking into account local constraints (e.g. TMA size, environment, TSAs, complexity of arrival/departure flows);
  - Continuous reliance on vertical separation for a certain duration (parallel sequencing legs) with potentially more severe consequences in case of failure.
- Enablers:
  - None (see ‘P-RNAV specific’ above), cf. use of existing technology.
- Operating method:
  - Need for efficient traffic metering at the Point Merge system’s entry in order to avoid too frequent sequencing legs run-off (or use of holding stacks);
  - Possible sensitivity to perturbations (e.g. wind) or aircraft performance according to design options (see §8);
  - FMS or ground FDPS route used for computations vs. actual route flown; resulting potential errors in estimates, and impact on fuel management<sup>31</sup>;
  - Need for specific recovery procedures, specific constraint of compatibility with Point Merge route structure.

<sup>29</sup> Although ICAO has recently defined that, when a ‘Direct To’ is being followed by the aircraft following an ATC instruction, the air traffic controller remains primarily responsible for terrain clearance (see §12.3).

<sup>30</sup> These issues have to be balanced against other benefits –in the frame of trade-offs between e.g. capacity and flight efficiency or environment, and/or predictability of 2D flight path versus flexibility of flight path adjustments. In both cases, there is an impact on the ability to optimise vertical profiles (also see the notes at the end of §4.2).

<sup>31</sup> Actually applies to other types of P-RNAV procedures such as e.g. ‘trombone’ routes.

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### 5.3.4 Associated Human Factors

The main related KPAs are here operability and safety. P-RNAV human factors in terminal airspace include:

- Acceptability issues for air traffic controllers related to change in operating method:
  - Method being less demanding and repetitive, risk of controllers becoming bored or having less job satisfaction and/or being less vigilant (the risk of a reduction in vigilance may need to be addressed through e.g. safety awareness campaigns and recurrent training).
  - Risk of controllers' de-skilling with regards to open-loop vectoring (simulation recurrent training might, in future, be required to keep controllers' skills up to the level required to cope with anomalies, i.e. unexpected/non-nominal situations).
- Feasibility issues for air traffic controllers:
  - Handling of mixed equipage and of non-nominal or abnormal situations;
- Acceptability issues for flight crews:
  - Related to change in working methods.
- Feasibility issues for flight crews:
  - None identified.

In addition, the following human factors could specifically need to be considered with Point Merge:

- Acceptability issues for air traffic controllers related to change in operating method:
  - Change in roles and task allocation between controllers;
  - Procedure more flexible than existing P-RNAV procedures (involving a fixed route or route changes with defined waypoints), but less than open-loop vectoring with potentially more frequent switch to alternate procedures (e.g. radar vectors);
  - Unusual merging on a point (rather than an axis) for terminal airspace;
  - With more time spent proportionally in P-RNAV (than e.g. trombone procedures), impact of global reversion to vectors (even though it should be a rare event);
  - Perception of larger airspace required, and longer distance flown, than with current procedures – due to published procedure involving the longest route.
- Feasibility issues for air traffic controllers:
  - Impact on controllers' team work and co-ordination;
  - Differential effect of strong winds due to PMS geometry.
- Acceptability issues for flight crews:
  - Unusual situation, flying on a sequencing leg with vertical separation from opposite traffic on parallel leg;
  - Subjective implication of a published procedure involving a long route (however this is similar to some existing P-RNAV procedures such as e.g. trombone routes)
- Feasibility issues for flight crews: none identified.

### 5.4 Essential requirements and recommendations

This section provides essential requirements and recommendations for Point Merge, that are related to the core principles and high level description of the procedure (as per §5.1), and applicable to the main design options (identified in §5.2 above). These requirements are expressed according to the following themes: Route structure (§5.4.1), Operating Method (§5.4.2 to §5.4.7), Human Factors including compatibility with conventional procedures (§5.4.8), Charting (§5.4.9), and Air and Ground enablers (§5.4.10).

#### Notes:

1. Some of these requirements and recommendations reflect information already provided in the overview of the operating method above, while others may actually be derived into more specific requirements (See §6, §8 and §9).
2. The main safety requirements that were identified or confirmed as part of the initial safety assessment are also covered here. More specific details on the rationale for these requirements are given in the analysis of differences between Point Merge and current procedures (§6 below).

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#### 5.4.1 Route structure

1. The equidistance property to the merge point is key to Point Merge procedure, as it enables a simple and intuitive operating method, and especially allows determining with sufficient accuracy the appropriate time to issue the ‘direct-to’ instruction. Therefore, the design of the sequencing legs shall ensure:
  - a. iso-distance: the shape of each sequencing leg shall be such that aircraft are kept (approximately) at the same distance from the merge point while flying along the leg (i.e. it is close to an arc of circle);
  - b. equidistance: distinct sequencing legs shall be (approximately) located at the same distance from the merge point.
2. To the extent possible, the route design should exhibit an overall symmetry<sup>32</sup>, so as to keep the operating method simple and intuitive – as regards the determination of sequence order, and of the appropriate time to issue the ‘direct-to’ instruction (see §8.3.1, §8.2.10).
3. In accordance with terminal airspace design guidelines<sup>33</sup>, the design of the route structure shall enable strategic de-confliction between arrivals from different flows (in addition to strategic de-confliction between arrivals and departures), before the sequence is built. In particular, sequencing legs shall be appropriately separated in the lateral and/or vertical planes (see §8.2.1, §8.2.8).
4. Parallel sequencing legs shall be vertically separated for the following reasons:
  - a. Due to the equidistance property, they are not expected to provide lateral separation by design;
  - b. As aircraft from the outer sequencing leg will generally cross the inner leg once instructed ‘direct-to’ the merge point, lateral separation between aircraft from different arrival flows cannot be ensured by design.
5. A sufficient lateral distance shall be considered between two parallel legs so as to avoid cluttering of ATCO’s display. Nevertheless, this distance shall still be compatible with the (approximate) equidistance requirement; also note that this de-cluttering requirement is related to the display range<sup>34</sup>.
6. Waypoints in a Point Merge system (including the merge point) shall be fly-by waypoints, in accordance with Ref [10], §4.3.2.1 – with the exception of the last point at the end of the sequencing leg in the ‘closing part’ of the procedure which may be a fly-over waypoint (see §7.4.1).
7. As for any airspace (re)design process, procedure designers should consider the effect of TCAS, in particular to ensure that the risk of TCAS nuisance Resolution Advisories (RAs) is minimised as far as possible (see §12.1 and §5.4.2 below).

Note: There are known issues regarding the risk of confusion on the R/T for FL100/FL110<sup>35</sup>. Current ICAO phraseology recommendations already provide mitigation for these issues. Nevertheless ANSPs implementing Point Merge may elect to avoid using FL100 and FL110 simultaneously e.g. for parallel sequencing legs.

<sup>32</sup> This results in more specific requirements/recommendations – e.g. same distance to go from the legs in multiple PMS (§8.3.1), or angles in a PMS (§8.2.10).

<sup>33</sup> Cf. [9], Part C, §5.4.2.

<sup>34</sup> Therefore a trade-off has to be considered between these two requirements, as regards the operability aspects of Point Merge. For instance, initial validation has shown that with 20 to 25nm between the sequencing legs and the merge point, a 2nm separation between the sequencing legs is a good compromise; with 15nm to the merge point, it may be preferable to use 1nm separation between the sequencing legs, possibly subject to further safety assessment.

<sup>35</sup> See EUROCONTROL Level Bust Briefing Notes:  
[http://www.skybrary.aero/solutions/levelbust/BNNotes/BN\\_Gen1.pdf](http://www.skybrary.aero/solutions/levelbust/BNNotes/BN_Gen1.pdf)

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#### 5.4.2 Operating method - General

1. In order that the Point Merge operations achieve the maximum efficiency, flight crew should implement ATC instructions promptly<sup>36</sup>. In addition, timely/appropriate compliance must be confirmed by controller monitoring (in fact, current radar vectoring operations already require prompt implementation).
2. As for any procedure involving RNAV-flown turns (e.g. fly-by transitions), ATC shall take into account the variability in aircraft turn performance so as to maintain safe separation between successive aircraft on the same sequencing leg, all along that leg (especially in case of segmented sequencing legs). An adapted along track buffer might therefore need to be added to the standard longitudinal separation between aircraft flying on a segmented sequencing leg. On the other hand, an excessive extra separation should be avoided as it would not allow the maximum landing rate to be achieved in all cases (see Ref[11], §1.5).

#### 5.4.3 Operating method - Entry conditions

1. Traffic presentation is a key aspect for Point Merge operations. This includes both longitudinal and vertical aspects.
2. Requirements related to longitudinal aspects of traffic presentation at PMS entry:
  - a. Longitudinally, in contrast to open-loop vectors, the new procedure involves a path stretching capacity that cannot normally be extended (unless radar vectors and/or holds are used to cope with unexpected/non-nominal situations). Thus arrival flows shall be properly metered at the Point Merge system entry, so as to avoid sequencing legs run-off as far as possible – or even to use nominally only a portion of the sequencing legs (see §12.2).
  - b. Speed restrictions may also be defined at certain waypoints in a Point Merge system. In particular, if it is the intention of ATC to reduce all aircraft to a common speed when they enter the sequencing leg so as to ease spacing maintenance along the leg and ensure homogeneous conditions prior to instructing aircraft ‘direct-to’ the merge point, this should be published as a speed restriction at the entry waypoint. It may then be desirable to also publish an altitude restriction at the same waypoint to ensure that all P-RNAV systems take account of the speed restriction (Ref [24]).
  - c. Speed reductions prior to entering the sequencing legs also enable absorbing more delay with same leg length. A trade-off may be needed between using speed values that are high enough after the direct-to (with respect to normal descent profiles), and still low enough while along the legs (to enable sufficient delay absorption)<sup>37</sup>.
3. Requirements related to vertical aspects of traffic presentation at PMS entry:
  - a. In case it is considered necessary to keep the aircraft at a specific level/altitude when flying along the sequencing legs (e.g. parallel legs with levelling-off), then ‘at’ altitude restrictions shall be defined for the start points of these legs, (Ref [24]).
  - b. Furthermore, in order to allow some time for pilots and ATCOs to detect a potential level bust, in particular mitigate the risk of an aircraft still being in descent whilst entering the sequencing leg in case level-off is required, the level restriction at the leg entry shall be published on a point ahead of the sequencing leg, ensuring that the aircraft levels off prior to entry.
  - c. Published vertical restrictions may also need to be placed at a point before the leg entry in order to minimise ACAS nuisance alerts in case of parallel sequencing legs with level-off (see §12.1). When possible, a single restriction should be defined so as to fulfil both level bust-, and ACAS RAs-related requirements.

<sup>36</sup> Ref[13], Flight Ops and Crews Information Notice, states that in the context of a P-RNAV procedure, “route modifications in the Terminal Area may take the form of radar headings or ‘direct to’ ATC clearances and the flight crew must be ready to react promptly.”

<sup>37</sup> In case the Point Merge system is used in Approach to integrate arrival flows to the runway after the IAF (see §9.1), an IAS value close to 220kts would be a good compromise when the sequencing legs are designed around FL100 (lower speeds could be used at lower levels – e.g. 200kts around FL70).

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#### 5.4.4 Operating method - Plan/prepare, start building the sequence: from PMS entry to ‘direct-to’

1. In order to ensure that there is no inadvertent descent while aircraft are flying along the sequencing leg, the minimum altitude for the leg should be published as an ‘at or above’ altitude restriction (or an altitude window) at its last waypoint (Ref [24]). If the route structure involves levelling-off along the leg, this restriction should be defined as an ‘at’ level/altitude restriction for the end point of the leg with the same value as the restriction at its entry point (see §2 above)<sup>38</sup>.
2. Provision shall be made for the use of a spare/additional level (or 1000 feet) for each sequencing leg. Such an additional level may be located above or below the considered leg (possibly between the sequencing legs). It would for instance give ATC more time to react in case an aircraft unexpectedly descends while flying along the highest of two parallel sequencing leg, or in case of metering problem at the entry of the Point Merge system, and also enable coping with cases where there would be a risk of longitudinal separation infringement between two successive aircraft on the same leg. This spare level may also be used to separate vertically flights exiting from the same hold located ahead of the sequencing leg entry (as they are not expected to be separated using vectors anymore in an RNAV environment).
3. Provision shall be made for sufficient margin in longitudinal separation between successive aircraft on the same leg in order to account for the risk of loss of (horizontal) separation when the first aircraft turns to the merge point.

#### 5.4.5 Operating method - Build (finalise) the sequence: ‘direct-to’

1. As already remarked in §5.1, the issuance of the “direct-to” instruction is pivotal to the Point Merge technique and its performance aspects, as it establishes both the sequence order and an initial inter-aircraft spacing. At this stage, a buffer in spacing with the preceding aircraft shall be included, compared to the targeted spacing at the merge point. This is intended to:
  - a. Subsequently enable efficient spacing adjustments solely relying on speed control– subject to the available speed range when flying a CDA towards the merge point, and/or
  - b. Avoid upstream propagation within the Point Merge system of speed reductions after the merge point (especially if the Point Merge system is located in the Approach, with speed reductions on final).
2. When issuing the direct-to instruction, ATC should also account for the approximation in iso-distance to the merge point due to sequencing legs geometry – each segment of a leg being at a smaller distance to the merge point on its middle part than on its extremities. Nevertheless, it is anticipated that the order of magnitude of this uncertainty will usually be negligible compared to the necessary spacing margin to allow subsequent spacing maintenance through speed control (as mentioned above). Moreover the inter-aircraft spacing accuracy that is necessary at this stage remains easily achievable thanks to the range rings/iso-distance markers displayed on the controllers’ screen.
3. ATC should also take into account the variability in aircraft turn performance when the lead aircraft turns to the merge point, in certain geometries involving large track angle changes at waypoints along the sequencing legs (see §8.2.10). This will also be a reason to include an adapted along track buffer as extra longitudinal separation.

#### 5.4.6 Operating method - Maintain the sequence: After the ‘direct-to’ and until PMS exit

1. Once direct to the merge point, in case of parallel sequencing legs, training shall highlight the need to ensure that lateral separation with aircraft on the other sequencing leg is achieved before issuing the descent clearance from the sequencing leg level/altitude. In addition, to the extent possible in that case, the descent clearance should be systematically dissociated from the direct to clearance (this is intended to mitigate some of the risks related to routine and loss of vigilance).
2. In case of parallel sequencing legs, the leg closest to the merging point (‘inner leg’) should in so far as possible be designed at the highest altitude. It would diminish the risk of separation infringement in case an aircraft descends unexpectedly just after being instructed to turn direct-to the merge point (see details

<sup>38</sup> Note that these recommendations may be subject to further safety assessment (if the aircrew is flying the procedure with VNAV engaged, such published restrictions might ‘hide’ an erroneous FL/altitude selection lower than the cleared one, in which case upon implementing the direct-to turn, the restriction would not be applicable anymore and the aircraft might immediately descend, resulting in a FL bust).

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in §8.2). In addition, all other things being equal, this would enable clearing aircraft for descent earlier after the turn towards the merge point.

#### 5.4.7 Operating method - Exit conditions

1. It is recommended that an appropriate altitude restriction in the form of ‘at or above’ or vertical window is defined at the exit of the Point Merge system and/or at its merge point. This will help to influence the vertical profile calculations once the aircraft has been cleared inbound (Ref [24]).
2. A published speed restriction may be defined at PMS exit, or at the merge point, in order to ensure an homogeneous flow at the exit of the Point Merge procedure.

#### 5.4.8 Human Factors, compatibility with conventional procedures

1. The use of conventional ATC procedures (vectors) remains possible when needed, e.g. for non-equipped traffic, alternative procedures in non nominal situations or abnormal cases. However it shall be adapted to the Point Merge environment so as to ensure compatibility with its normal operation<sup>39</sup>. Specific procedures for mixed traffic and for recovery of unexpected events shall be defined and included in the recurrent training.
2. ATCOs vectoring skills shall be maintained through recurrent training.
3. Adapted measures shall be taken to mitigate the risk of loss of vigilance for ATCOs (including e.g. recurrent training, safety management processes).

#### 5.4.9 Charting

1. The Point Merge procedure should be detailed in the AIP, or in a supporting AIC.
2. The waypoint names in a Point Merge system shall conform to naming conventions such as those mentioned in Ref [10], §4.3.3. In particular, waypoints on the sequencing legs could be identified using the alphanumeric naming conventions. The merge point shall be considered as a strategic waypoint to ATC (see Ref [10], §4.3.1.3, and Ref [24]), and thus be named using 5 letter globally unique pronounceable ICAO Name codes (Ref [10], §4.3.3.6).
3. The location of the merge point should be co-ordinated with ATC and with the navigation data providers, to ensure consistent waypoint use in all cases, especially in case the merge point is close to the FACF (Final Approach Course Fix) in a precision approach procedure (see Ref [24]).
4. The charts should not be cluttered with detailed notes about the concept apart from a note to stating ‘Point Merge procedures in operation, expect clearance direct to merge points (WPT NAMES) once past IAF. CDA profiles to be followed once inbound to the merge point’, or a similar statement (Ref [24]).
5. In order to allow for sufficient flight crew situation awareness, it is recommended, especially in case of parallel sequencing legs of opposite directions, that the published procedure includes a chart representing all concerned STARs involving the same merge point.

Note: a sample chart is provided in §10.4, including examples of published speed and altitude restrictions.

#### 5.4.10 Enablers

This section details the functional capability requirements for both air and ground. An overview of the expected operational environment is available in §13 below.

#### Communications

1. Air-ground communications using radio-telephony will adequately support the new procedure.

#### Navigation

1. P-RNAV fits (with a +/- 1nm lateral navigation accuracy) all the required airborne capabilities to fly a Point Merge procedure, i.e. at least the following functions or performances:
  - Lateral navigation,
  - Fly-over and fly-by turns (i.e. including turn anticipation),

<sup>39</sup> Due consideration was given to this specific requirement when defining alternative and abnormal procedures in §7.2, §7.3 and §7.4 below.

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- A “direct-to” capability,
  - Navigation database requirements (i.e. memory capacity on older aircraft may be insufficient).
2. Moreover, it is expected that the (re-)design of route structures in terminal airspace, in order to support the new procedure will require the definition of new points, with sufficient design flexibility (e.g. for the merge point(s)). Such flexibility will generally only be achieved via area navigation (RNAV). Indeed, conventional navigation would constrain the definition of points depending on available ground navigational aids. Consequently **an “equipped aircraft” in the frame of this document designates an aircraft that is P-RNAV equipped and for which the operator has obtained P-RNAV airworthiness and operational approval from the State Regulator<sup>40</sup>.**
  3. A vertical Navigation (VNAV) capability is not mandatory for P-RNAV. It should be possible to fly a published descent profile conventionally/manually, given adequate flight deck information and appropriate flight crew training (Ref[44], Annex D). Therefore, **VNAV capability is not considered a required enabler for Point Merge, even in the case when the procedure includes published vertical restrictions.**
  4. As far as non equipped aircraft are concerned, the lowest common denominator must be assumed; thus **in the present document a non equipped aircraft will be assumed to lack even a ‘direct-to’ capability.**

Notes:

1. P-RNAV approval includes (cf. Ref [12]):
  - Airworthiness compliance statement, through e.g. TGL-10 (Ref [44]) compliance statement by Original Equipment Manufacturer, for the aircraft type with delivered navigation system;
  - Navigation database integrity, in accordance with ED76 (Ref [43]);
  - Compliance with operational requirements (procedures, crew training, etc..).
2. The Point Merge procedure is radar monitored and does not rely on turn containment.
3. At this stage it is not expected that additional airborne functions such as aircrew alerting will be required (although in the future it may be possible to design more efficient lateral or vertical profiles with the advent of PBN – also see §8.2).

**Surveillance**

1. The new procedure will be supported by radar surveillance (classical secondary surveillance, or Mode S elementary surveillance); no additional surveillance capabilities are required.

**Controller support tools**

1. As far as ground systems are concerned, the main enabler foreseen at this stage is a pre-defined set of range rings, or markings, displayed on the controller’s working position, e.g. centred on the merge point. Such markings could be part of the controller’s screen, and thus are not expected to require new capabilities for the ground system.
2. A clear indication of aircraft RNAV equipage/capability will also be needed on the controller’s display, and/or on paper strips, based on flight plan data. (Note: this is already provided for by the requirement for the insertion of the letter ‘P’ in the FPL denoting that a particular aircraft is P-RNAV approved). In addition, it should be kept in mind that flight crews are required to inform ATC if they cannot accept a P-RNAV procedure for which they have been cleared.
3. The controller’s display shall enable the marking of specific aircraft, e.g. in order to mitigate the risk of confusion over an equipped aircraft that would be vectored out of the procedure. Note that this requirement is actually applicable to any P-RNAV procedure (and this function already exists in most recent ATC systems).
4. The metering of arrival flows prior to their entry in a Point Merge system, which is required with a certain accuracy (see §7.1 and §12.2), may be achieved through the use of an AMAN.
5. Finally, ground-based conformance monitoring tools such as MONA are not initially considered as being required for the new procedure – although their use could bring additional benefits.

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<sup>40</sup> It is nevertheless left to ANSPs and national authorities to decide which airborne navigation performance and/or equipment to mandate for a local/specific Point Merge procedure.

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## 6. Differences between new and current procedures

While Point Merge does not rely on any new principle of operations, it introduces differences regarding the operating method compared with standard ATC and/or current P-RNAV procedures. The consequences of these differences may be of a positive or negative nature – resulting respectively in potential benefits or limitations (or constraints).

The present section provides an initial analysis of these key differences (based on §4 and §5). It forms both an input and a structuring framework, enabling, separately from this OSED, the further development of a case-based approach – including e.g. Safety, Human Factors, Environment, and Business cases. As the analysis was originally carried out to support an initial safety assessment, it is focussing on the safety implications.

This section is divided into three different levels of analysis, aiming at giving complementary views:

- a concept level analysis (§6.1), based on the key principles of the new procedure;
- a ‘task level’ analysis (§6.2), based on ATC tasks in terminal airspace;
- a ‘state and transitions’ analysis (§6.3), based on sequence of steps in the operating method.

These three views are then consolidated into a set of potential requirements (§6.4).

The ‘concept level’ analysis applies to both TMA and E-TMA; the ‘task level’ and ‘states and transitions’ analyses consider the TMA and the particular design option involving parallel sequencing legs vertically separated with level-off. That option was selected for the analysis as it is the most constraining one.

Point Merge being a P-RNAV application, it inherits from general P-RNAV characteristics; however it also introduces its own specific properties. The identification of key differences with current procedures shall therefore distinguish between those aspects that are due to the introduction of P-RNAV in general, and those that are specifically due to Point Merge. While the baseline for comparison includes both vectoring and currently existing P-RNAV applications (including e.g. fixed routes supporting STAR-based CDAs, or ‘trombone routes’ as depicted in §4), this section focuses on Point Merge-specific differences.

### 6.1 Concept level analysis

The analysis at the level of concept and principles is organised along two aspects: route structure and operating method.

#### 6.1.1 Route structure characteristics

Current capacity-oriented P-RNAV procedures deployed in some TMAs (e.g. ‘trombone routes’ as depicted in §4) tend to replicate pre-existing and/or typical vectoring patterns. In contrast, the Point Merge route structure is built upon a **2D/3D converging (cone) shape reflecting the functional objective** of merging arrival traffic, and it is **intrinsically linked to the operating method**. At this level of analysis, essential and invariant characteristics of the structure include (as depicted in §5.1.3):

- a **single pre-defined merge point**, followed by a common path and
- sequencing legs **at iso-distance/equidistance** from the merge point.

Compared with current procedures, the resulting positive (+) and negative (–) consequences are as follows:

- (+) clearer and more intuitive structure of the route for merging arrival traffic;
- (+) no late dispersion of trajectories, and actually a standard delivery after the merge point (in approach standard ILS interception in case of precision approach, or seamless transition to an RNAV approach);
- (–) different constraints of applicability due to the specific cone-shape – in particular to highly constrained terminal airspace e.g. multiple airports, small TMA, terrain (cf. §8 and §9);
- (–) path stretching capability and maintenance of “runway pressure” (including capability to fill gaps in the sequence due to e.g. go-around, late direct-to) not simultaneously maximised<sup>41</sup>.

<sup>41</sup> It shall be kept in mind that any given P-RNAV procedure is not expected to provide maximum benefits with respect to all KPAs at the same time. Instead, each procedure may provide a different trade-off between e.g. capacity, fuel efficiency, environment, predictability. This notion of trade-off is detailed in §5.3 above.

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Note: the two “negative” consequences above are not related to safety and will not result in potential safety requirements.

Another key characteristic of the Point Merge route structure is a **predefined horizontal (and vertical) envelope**: path stretching patterns are all contained in the same lateral envelope of trajectories, defined by the sequencing legs, the merge point, and closed by the “legs run-off procedure” (see §5.1.4). Regarding the vertical dimension, the introduction of a route structure also enables the definition of vertical restrictions along the route. Compared with vectors and even with other capacity-oriented P-RNAV procedures such as trombone routes, with Point Merge, the three dimensional envelope of trajectories is geometrically structured within simpler, cone-shaped boundaries. These differences induce the following consequences:

- (+) pre-defined and increased 3D containment of trajectories; as a result, from a safety perspective, easier strategic de-confliction from other flows / terrain / areas;
- (+) capacity directly determined by the route structure (as for any closed procedure);
- (-) strict upper limit in path stretching/delay absorption (i.e. pre-defined length of sequencing legs), with a risk of frequent sequencing legs run-off if traffic is not properly metered (as for any closed procedure);
- (-) subjective, technical and operational implications of ‘long route’ being published and used<sup>42</sup> (as for e.g. P-RNAV “trombones”).

### 6.1.2 Operating method characteristics

Compared to today’s procedures involving vectors or P-RNAV routes, the Point Merge operating method relies on a **systematic sequence of actions**, attached to predefined geographic locations including **merging to a single point** (instead of merging to an axis), and **path stretching along sequencing legs** (at the same distance from the merge point). In particular, while in current day operations, the sequencing, metering and separation aspects<sup>43</sup> of arrival flows integration are often overlapping, Point Merge introduces a clearer split:

- Sequencing (ordering) is directly related to the order in which the controller issues the ‘direct-to’ instruction;
- Inter-aircraft spacing (for separation or metering purposes) is directly related to the times when the ‘direct-to’ instruction is issued, and to subsequent speed control.

The positive and negative consequences are:

- (+) standardised, more intuitive, and clearer/easier method; easier training;
- (+) systematic method facilitating detection and monitoring;
- (+) instructions issued early, possibly at or above FL100, hence better integration with pilot tasks;
- (+) improved controller anticipation and situation awareness;
- (+) improved pilot situation awareness;
- (+) improved predictability leading to easier planning and coordination for arrival management (clearer sequence order and visual detection/anticipation of risk of capacity overruns);
- (-) in terminal airspace, unusual merging on a point rather than an axis<sup>44</sup>;
- (-) less flexibility for the controller (potentially resulting in more frequent switch to alternate mode);
- (-) repetitiveness for the controller (risk of: loss of vigilance, boredom and job satisfaction issues)<sup>45</sup>.

<sup>42</sup> Typically, feeling that the procedure involves more track miles and requires more airspace, systematic inaccuracies in FMS or ground FDPS computations until the direct-to. However when on course to the merge point, there is no uncertainty anymore on the FMS/FDPS lateral computations.

<sup>43</sup> See §3.3 and §16.1. Point Merge applications to metering and/or separation are further detailed in §9.

<sup>44</sup> When presented with Point Merge, approach controllers initially felt that convergence on a point may be seen as potentially ‘creating conflicts’. However after limited practice/exposure, this concern disappears, as aircraft are longitudinally spaced as per the operating method, traffic pattern is structured and situation is easy to monitor. Note also that flows integration on a point is used today in some ACC arrival sectors (extended TMA).

<sup>45</sup> As for any P-RNAV procedure; however it is anticipated that the risk of controllers becoming bored/less vigilant or having less job satisfaction may need to be specifically addressed with Point Merge, due to the easy, systematic nature and repetitiveness of the operating method.

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The method involves **closed loop interventions**, such that aircraft are kept on lateral navigation (even in high traffic), with the following consequences:

- (+) enhanced pilot situation awareness;
- (+) continued and facilitated FMS computations;
- (+) improved ground trajectory prediction, leading to improved controller's tools (e.g. AMAN);
- (+) more effective CDM, airport turnaround and airlines operations<sup>46</sup>;
- (-) less flexibility for the controller;
- (-) risk of loss of controllers vectoring skills<sup>47</sup>.

Note: keeping aircraft in lateral navigation mode enables continuous descents even under high traffic load. This is an example of impact on other KPAs and may feed e.g. an environmental case or a business case.

The method also requires **fewer tactical interventions** which in turn has the following consequences:

- (+) less workload (for both controllers and pilots) and increased controller's ability to manage longer and sustained peaks of traffic;
- (+) less communications (load, errors);
- (-) less flexibility for the controller;
- (-) repetitiveness for the controller.

Finally, **alternate operating methods** (vectors for non equipped aircraft/unexpected situations) bear a **specific constraint of compatibility with the normal Point Merge operating method**<sup>48</sup>, resulting in:

- (+) structured and pre-defined alternate procedures, close to normal Point Merge operations;
- (-) need to define and train to alternate procedures (e.g. for specific recovery);
- (-) risk of confusion between traffic under normal procedure and traffic under alternate procedure (reminder, transfer, coordination);

## 6.2 Task level analysis

The task level analysis links the Point Merge operating method and generic air traffic control tasks defined in §3.3 above. The case analysed here involves the application of Point Merge in Approach airspace (where inter-aircraft spacing ultimately aims at separation towards the runway), with parallel sequencing legs and level-off. In this context, ATC tasks for arrival flows integration relate to two main objectives that may appear as contradictory (see §3.3.1):

- Convergence in all dimensions (lateral, vertical and longitudinal);
- Separation in at least one dimension (lateral, vertical or longitudinal).

### 6.2.1 Convergence tasks

The route structure reflects the convergence objective, and **convergence is done on a point** with the following consequences on tasks:

- (+) standardised convergence tasks, "naturally" embedded in the procedure;
- (-) *none identified*.

In the case studied here, while along sequencing legs, there is a '**steady state**' in convergence (i.e. no convergence nor divergence): laterally, as the legs are at equi-distance/iso-distance from the merge point; longitudinally as inter-aircraft spacing is already achieved for aircraft along the same leg; vertically, due to the levelling-off constraint for vertical separation. This steady state is **followed by near-simultaneous**

<sup>46</sup> CDM tools enabling a balanced trade-off between predictability, and flexibility in terms of changes in sequence order); the increase in predictability and in situation awareness is also expected to enable more consistent CDM requests from airlines, airport operators and/or tower ATC.

<sup>47</sup> As for any P-RNAV procedure; however it is anticipated that the risk of controllers' de-skilling with regard to vectoring might increase with Point Merge as vectors are only expected to be used to recover from unexpected situations or for non equipped aircraft.

<sup>48</sup> I.e. unless global reversion to vectors is unavoidable (generally only in the event of a global failure or perturbation) recovery procedures should be defined so that a 'problem' aircraft remains easy to integrate with other aircraft in the sequence which, to the extent possible, should be kept under the normal Point Merge procedure.

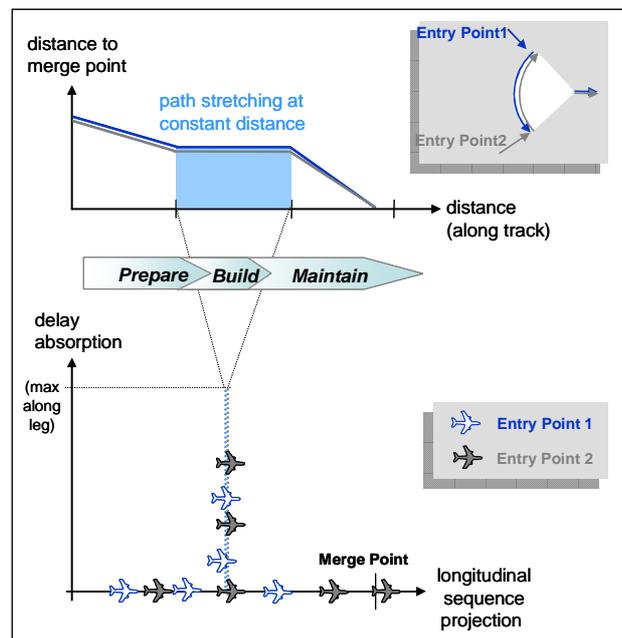
**convergence along all dimensions** (Figure 6-1). The consequences are:

- (+) easy and comfortable path stretching phase;
- (+) better controller anticipation and situation awareness;
- (-) less flexibility.

**Lateral and vertical convergence only require one instruction each** (resp. Direct-To, and descent). In contrast, current procedures (vectors or P-RNAV) involve a succession of lateral and vertical instructions. Longitudinal convergence is initiated through the lateral convergence, then refined with speed instruction(s).

These differences results in the following consequences:

- (+) less communications (load, errors); in particular, reduced risk of FL busts;
- (+) uninterrupted descent;
- (-) lateral/longitudinal: less flexible, risk of loss of accuracy (inter-aircraft spacing larger than required).



**Figure 6-1. Lateral and longitudinal convergence with Point Merge**

## 6.2.2 Separation tasks

As stated in §3.3, separation task can be divided into:

- Maintain separation between distinct arrival flows (before merging);
- Maintain spacing/separation within each arrival flow (before merging) ;
- Create spacing between aircraft from converging arrival flows (when initiating merging);
- Maintain spacing within each converging arrival flow and after convergence (during and after merging).

Table 6-1 below maps the Point Merge operating method onto these generic arrival ATC sub-tasks<sup>49</sup> and stresses the main differences with today's practices.

<sup>49</sup> According to §3.2, there are other ATC tasks that are "peripheral" to arrivals integration. These include the separation from other flows, and from terrain or segregated areas. These are not addressed in the present section; as stated in §6.1.1 above, it is anticipated that the structured nature of Point Merge would facilitate these tasks thanks to an increased level of strategic de-confliction, subject to local constraints.

Phase in sequence management	What (separation tasks)	Where/When (with Point Merge)	How (Point Merge, parallel legs vertically separated)	Difference (with current operating method in TMA)
<b>PLAN/PREPARE THE SEQUENCE</b>	Maintain separation between distinct arrival flows	From PMS entry and along the leg	Vertical separation: design	Similar technique, but <b>more frequent use</b> (systematic)  Analogy with stacks: similar technique, similar frequency of use, but different context <sup>50</sup>
	Maintain spacing/separation within each arrival flow	From PMS entry and along the leg	Longitudinal spacing: speed control	Similar technique, similar frequency of use as with P-RNAV
<b>BUILD THE SEQUENCE</b>	Create spacing between aircraft from converging arrival flows	Along the leg, when appropriate spacing reached with the preceding aircraft	Longitudinal spacing (projection): path stretching (leg) followed by direct-to	<b>Different technique</b> (integration to a point instead of an axis)  Analogy with E-TMA: similar technique <sup>51</sup> , similar frequency of use, but different context <sup>52</sup>
<b>MAINTAIN THE SEQUENCE</b>	Maintain spacing within converging arrival flow and after	On course to the merge point, and until PMS exit	Longitudinal spacing: speed control	Similar technique, similar frequency of use (although different situation: speed control while merging to a point)

**Table 6-1. Separation tasks: differences between Point Merge and current operations**

These differences do not arise from the introduction of a new technique per se, rather from a different context of use: more frequent use of techniques already applied in TMA, use of a technique currently applied in E-TMA.

**“More frequent use”**: The **systematic reliance on a single dimension for separation between distinct arrival flows** (i.e. vertical separation by design between parallel legs) has the following consequences, compared to current procedures:

- (+) benefits from systematic separation by design: less ATC tactical interventions, easier task due to a single parameter to monitor for separation between flows, hence lower controller taskload;
- (-) increased sensitivity to perturbations (entry conditions i.e. level busts)
- (-) continuous maintenance of vertical separation for a certain duration (in airspace with aircraft in evolution);
- (-) in terminal airspace, unusual situation (close parallel legs of opposite direction with vertical separation)<sup>53</sup>;
- (-) risk of loss of separation in case of failure<sup>54</sup>;

<sup>50</sup> Beyond the analogy, there are differences with stacks (with positive or negative implications): on a sequencing leg, all aircraft remain stable (positive) while the leg level can be occupied by more than one aircraft at a time (negative).

<sup>51</sup> Although after giving a vector for path-stretching, controllers generally do not give a 90° Direct-To, but to be more accurate would give intermediate heading(s) followed by the Direct-To with smaller track angle change (e.g. 20° or 30°).

<sup>52</sup> Entry conditions: with Point Merge, aircraft are following possibly close parallel sequencing legs, vertically separated.

<sup>53</sup> As with convergence on a point, when first introduced to Point Merge controllers initially felt that this situation may be seen as unusual in TMA, and potentially hazardous. However after limited practice/exposure, this concern disappears as arrival flows are strategically de-conflicted with vertical separation, and situation is easy to monitor. Regarding the pilot acceptability, when presented with Point Merge in flight simulators, pilots did not express concerns, noting that the STARs for all legs will be published, and followed by aircraft on the ‘opposite’ leg and known from the crews.

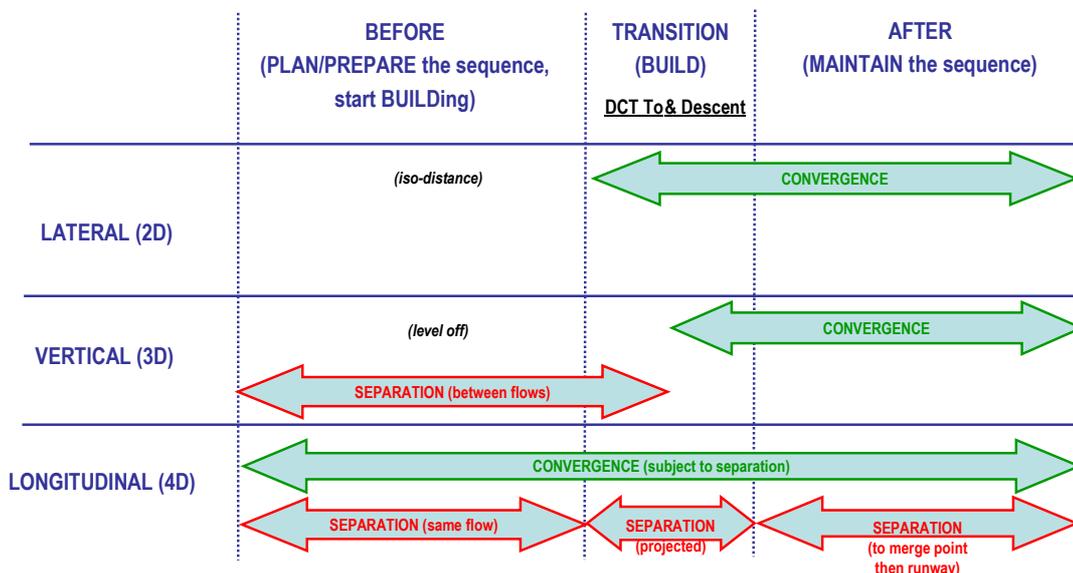
<sup>54</sup> This is actually similar to current En Route procedures with routes vertically separated; however there is in terminal airspace, where aircraft are in vertical evolution, the issue of level busts with more severe consequences, and therefore potentially specific requirements. In addition, an analogy with stacks can also be considered (see footnote above).

“**Different technique**”: the **integration of flows on a point** – instead of an axis, through a single instruction (Direct-To) results in the following advantages and drawbacks:

- (+) single intervention, and single parameter to monitor for the Direct-To;
- (+) fewer errors;
- (+) enhanced controller and pilot situation awareness;
- (-) increased risk of pilot or controller error due to systematisation (e.g. pilot picking up the direct-to instruction intended for another aircraft);
- (-) risk of loss of accuracy (inter-aircraft spacing smaller than required);
- (-) differential effect of winds depending on the geometry of the route structure, i.e. more risk to send an aircraft direct to the merge point at the wrong time;
- (-) need for specific recovery (see §6.1.2 above and alternate modes in §7);
- (-) systematic responsibility of controllers for terrain/obstacle clearance between the sequencing legs and the merge point<sup>55</sup>.
- (-) subjective implications of converging on a point<sup>56</sup>.
- (-) a reversion to vectors may involve more aircraft compared to e.g. trombone procedures<sup>57</sup>.

### 6.3 States and transitions analysis

To address the dynamic perspective, the present section considers the normal sequence of events, through a ‘states and transitions’ model (case of parallel sequencing legs with level-off). This model shows how convergence and separation are implemented, along the main phases of the operating method and across the three dimensions (Figure 6-2 below). After an overview of these dynamic aspects (§6.3.1), the analysis focuses on the main transitions between convergence and separation tasks and/or dimensions (§6.3.2, 6.3.3) and the prevention and mitigation of separation failures (§6.3.4).



**Figure 6-2. Convergence and spacing/separation with Point Merge**

<sup>55</sup> While this may not necessarily a drawback per se, it has to be taken into account when applying Point Merge in airspace with terrain issues.

<sup>56</sup> Controllers initially felt that aircraft converging in 3D to the same point, same altitude, in descent with only speed control to ensure separation may be unusual in TMA, and potentially hazardous as it may be seen as “creating conflicts”. However after limited practice/exposure, this concern disappears as appropriate direct-to instructions ensure longitudinal separation at the merge point, and situation is easy to monitor.

<sup>57</sup> When converging to the merge point, more time is spent proportionally under “spacing maintenance” (longitudinal spacing along a potentially ‘tight’ sequence), off the P-RNAV route. For these reasons, if one aircraft has to be vectored, there is an increased risk with Point Merge that other aircraft in the sequence may also have to be vectored.

### 6.3.1 Overview from a dynamic perspective

Based on Figure 6-2 above, the following states and transitions can be identified in relation with Point Merge, considering phases in the operating method (i.e. before, during and after merging):

- Laterally: initiation of convergence towards the merge point through the Direct-To instruction; before that, there is no lateral convergence along sequencing legs due to the iso-distance property.
- Vertically: initiation of convergence through the descent instruction; before that, there is no vertical convergence along sequencing legs due to the level-off (vertical separation between legs).
- Longitudinally: transition from same flow separation along the leg, to projected longitudinal separation towards the merge point (followed by longitudinal separation along a common path), again through the Direct-To; longitudinal convergence being an underlying objective in all states, subject to longitudinal separation requirement.

Consequently, in contrast with current operating methods, Point Merge involves a **successive reliance on a single dimension for flow integration** (typically: vertical separation between sequencing legs and longitudinal separation on a given leg, followed by projected longitudinal separation towards the merge point). This has the following consequences:

- (+) clearer steps, hence clearer task allocation between controllers;
- (-) controller acceptability issues: change in task allocation between e.g. approach controllers<sup>58</sup>;
- (-) increased sensitivity to interferences during transitions between dimensions (e.g. from vertical separation along parallel sequencing legs, to longitudinal separation when direct-to the merge point);
- (-) less flexibility in particular regarding the lateral dimension (solely relying on speed control after direct-to).

The safety implications of the last two negative consequences above are addressed in §6.3.2 and §6.3.3 below.

### 6.3.2 Vertical convergence versus separation

There are interferences in the lateral and vertical dimensions during transitions: when an aircraft leaves its sequencing leg, being instructed Direct To the merge point, it is not yet laterally separated (at least by design) from aircraft on the other leg(s). Indeed, if it was flying on the outer leg, its horizontal path will cross the inner leg; if it was flying on the inner leg, the distance between the legs may anyway not provide lateral separation. Therefore, during that transition, vertical separation shall be maintained until lateral separation is achieved i.e. when clear of traffic from the other leg(s). A simple way of ensuring that continued vertical separation is to dissociate the descent instruction from the Direct To (Figure 6-3 below).

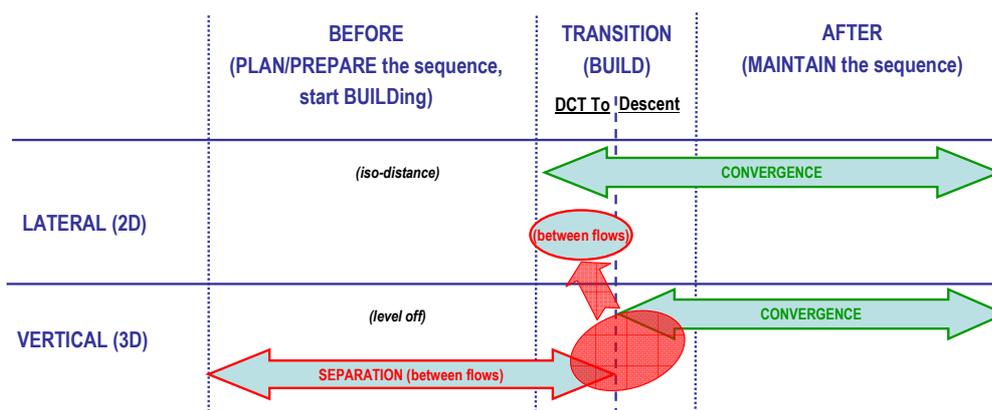


Figure 6-3. Vertical and lateral interactions during transitions

<sup>58</sup> This is valid for any change in operating method involving different task allocations. It is anticipated that this particular issue has to be addressed through an appropriate change management process by the concerned ANSPs, therefore it is not further developed here.

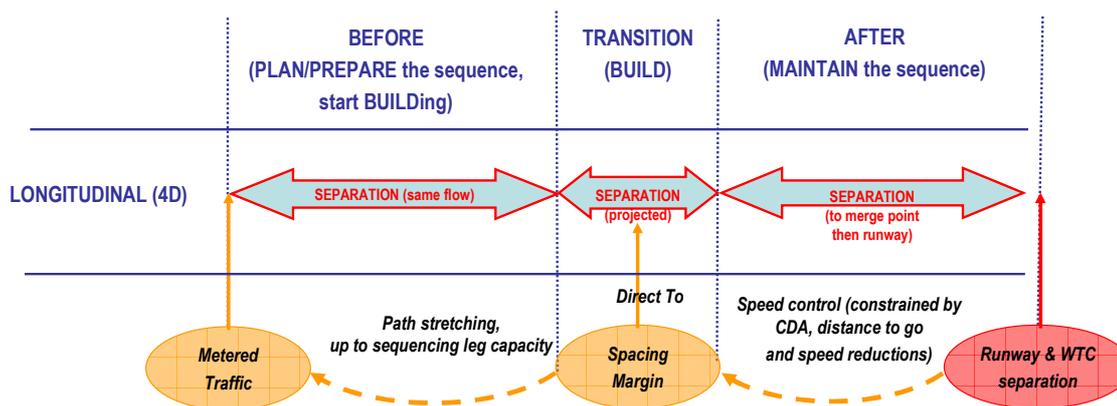
**Note:** designing the inner leg higher is a possible/partial prevention means, as in that case, aircraft can descend immediately when leaving the outer (lower) leg (see §8.2.8).

### 6.3.3 Lateral/longitudinal convergence versus separation

As illustrated by Figure 6-2 above, longitudinal separation is achieved continuously together with longitudinal convergence, for same flow aircraft, then merging aircraft (even though it is a ‘projected’ separation in the latter case). Therefore no particular interference issue is anticipated during transitions along that dimension.

With Point Merge, both lateral convergence and (projected) longitudinal convergence are initiated at the same time through the direct-to instruction after which inter aircraft spacing can only be adjusted through speed control. This systematic reliance on a single dimension for spacing along with natural speed reductions towards the runway induce a systematic backwards propagation of longitudinal constraints, starting from the runway separation criterion:

- A spacing margin needs to be considered when instructing the direct-to, in order to enable subsequent spacing maintenance for aircraft that are on course to the merge point, solely relying on speed control (in the context of a continuous descent and speed reductions, see §7.1.2);
- Traffic need to be metered before entering the sequencing legs so as to avoid too frequent occurrences of sequencing legs run-off (see §7.1 and §12.2).



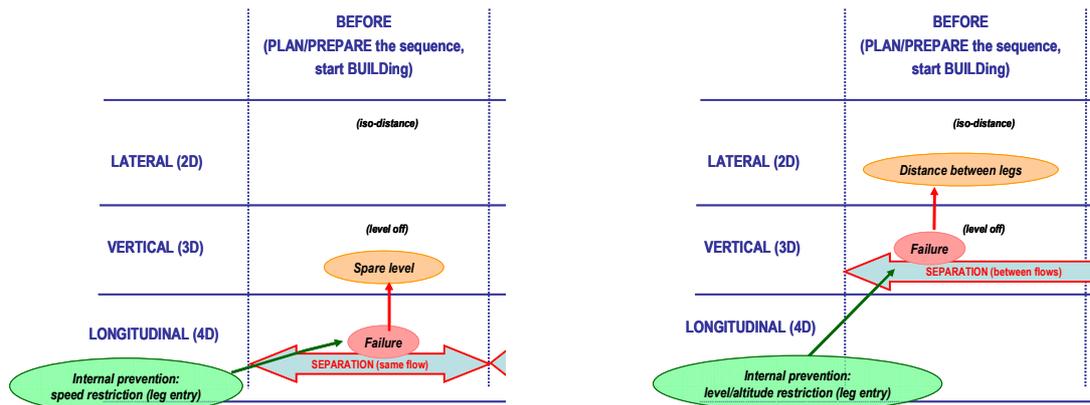
**Figure 6-4. Backwards propagation of longitudinal constraints**

### 6.3.4 Prevention and mitigation of failures

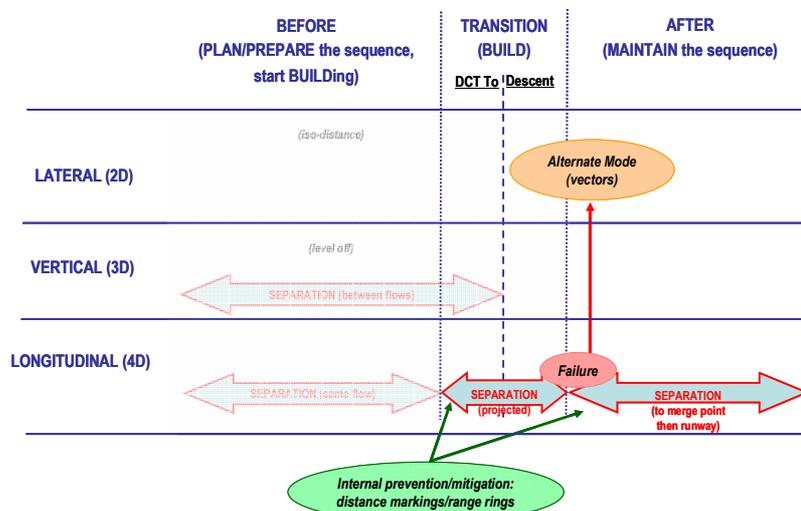
Point Merge differences with current procedures may induce specific separation failure modes (in particular: less flexibility, continuous reliance on vertical separation along legs, with potentially severe consequences in case of failure, increased sensitivity to perturbations e.g. regarding entry/external conditions). Consequently, there is a need to address those failure modes with specifically adapted means.

On the positive side, the structured nature of Point Merge enables to include in the procedure:

- failure prevention means, regarding entry conditions, along the same dimension as the considered potential failure (e.g. speed restrictions as prevention for longitudinal separation failure, or vertical restrictions as prevention for vertical separation failure – materialised in green in the figures below), in addition to training and system support as needed;
- failure mitigation means using a different dimension (e.g. spare level ) or structured alternate mode (e.g. vectors along a parallel pseudo sequencing leg) – materialised in orange in the figures below.



**Figure 6-5. Prevention and mitigation of failures: before the direct-to**



**Figure 6-6. Prevention and mitigation of failures: after the direct-to**

## 6.4 Consolidation

This section provides a consolidation of positive consequences (potential benefits) and negative consequences (limitations or constraints) identified in all views, i.e. ‘concept level’, ‘task level’ and ‘states and transitions’. This consolidation is structured along two main threads: consequences that are mainly, although not exclusively, related to safety and operability (which were the initial focus of the analysis), and consequences related to other KPAs. Within each of these two threads, four aspects are considered: route structure, operating method, human factors and system support. Finally potential requirements were derived from the negative consequences; they were confirmed through a safety workshop (Ref [26], [27]) gathering controllers’ and pilots’ feedback.

Note: it is recalled that the analysis focuses on the case of approach airspace and parallel sequencing legs with level-off.

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#### 6.4.1 Positive consequences

##### Consequences related to safety and operability

###### Route structure

- Clearer, more intuitive route structure;
- Easier strategic de-confliction (other flows, terrain, areas) due to 3D containment.

###### Operating method

- Standardised method (also related to harmonisation/interoperability<sup>59</sup> KPA);
- More intuitive and easier method (for both separation and convergence tasks);
- Systematic method facilitating detection and monitoring (controllers);
- Easier definition of metering requirements, easier planning and coordination for arrival management, (capacity directly determined by route structure, adherence easier to monitor);
- Standard delivery, i.e. in approach standard ILS interception in case of a precision approach, or seamless transition to an RNAV approach.
- Structured and predefined alternate procedure close to normal procedure;

###### Human factors

- Clearer controllers task allocation;
- Easier and comfortable path stretching phase;
- Fewer ATC tactical interventions;
- Less workload (controllers and pilots), hence increased availability for monitoring tasks;
- Less communications (load, errors),<sup>60</sup>
- Fewer operational errors (in particular reduced risk of level busts);
- Improved predictability and situation awareness (controllers and pilots);
- Better anticipation (controllers and pilots), with earlier instructions delivery (e.g. descent towards ILS interception altitude), possibly at or above FL100, hence better integration with cockpit tasks.

###### System support

- None identified

##### Consequences related to other performance areas

###### Route structure

- Uninterrupted/continuous descent from the sequencing legs (environment, flight efficiency KPAs);
- Predefined and contained trajectory dispersion – and no late dispersion (environment KPA).

###### Operating method

- Standardised operating method (harmonisation/interoperability<sup>61</sup> KPA);
- More effective CDM – improved interaction with airport turnaround and/or airline operations (flexibility, predictability, interoperability KPAs).

###### Human factors

- Less workload, hence increased controller's ability to manage longer/sustained peaks of traffic (capacity KPA);
- Easier controller training (cost effectiveness KPA).

###### System support

- Continued FMS computations and improved ground trajectory predictions (predictability KPA).

<sup>59</sup> Focus areas: homogeneous traffic flows, application of global standards and uniform principles (Ref [46]).

<sup>60</sup> Less communications is expected to 'mechanically' result in fewer errors; note that the systematic nature of the operating method may, on the other hand, induce errors due to e.g. repetitiveness (cf. §6.4.2).

<sup>61</sup> Focus areas: homogeneous traffic flows, application of global standards and uniform principles (Ref [46]).

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## 6.4.2 Negative consequences

### Consequences related to safety and operability

#### Route structure

- More stringent longitudinal delivery due to strict limit in path stretching (length of legs).  
→ *Potential requirements:*

○ Appropriately metered traffic prior entry point (as for any closed procedure).
--
- More stringent vertical delivery (reliance on vertical separation by design), inducing higher sensitivity to vertical aspects (performance, perturbations, failure) for:
  - separation assurance (including risk of loss of separation in case of failure), and
  - safety nets (including nuisance alerts and impact of resolution advisories<sup>62</sup>).
→ *Potential requirements:*

○ Published vertical restrictions before leg entry (possibly complemented by vertical rate adjustment);
○ Special attention on altitude monitoring (monitoring aids may be considered, see §5.4.10);
○ Definition of spare level(s) for sequencing legs;
○ Lateral distance between parallel legs (although no lateral separation objective);
○ Controllers and pilots training, awareness campaigns.
- Higher sensitivity to lateral aspects (performance, perturbations failure) including e.g. differential effect of wind.  
→ *Potential requirements:*

○ Controllers training.
-------------------------

#### Operating method

- Interaction between lateral (direct-to) and vertical (legs separation) aspects (risk of interference during transition between dimensions).  
→ *Potential requirements:*

○ Descent instruction delayed after (i.e. systematically dissociated from) the direct-to so as to ensure separation from aircraft on other leg(s);
○ Inner leg higher.
- Interaction between lateral (direct-to) and longitudinal (speed control) aspects (need to anticipate on separation maintenance solely relying on speed control).  
→ *Potential requirements:*

○ Need for spacing margin when issuing the direct-to instruction.
---
- Need to define and train to alternate procedures including handling of mixed equipage; risk that reversion to vectors involves more aircraft.  
→ *Potential requirements:*

○ Definition of, and controller training to alternate procedures.
---

#### Human factors

- Method less flexible (for controllers), risk of loss of inter-aircraft spacing accuracy and potentially more frequent switch to alternate mode.  
→ *Potential requirements:*

○ Controller training.
------------------------
- Risk of loss of controllers vectoring skills.  
→ *Potential requirements:*

○ Controller's recurrent training.
------------------------------------

<sup>62</sup> In addition to reducing the occurrences of nuisance ACAS resolution advisories through procedure design, local implementation studies should address the potential impact of ACAS RAs that would be triggered within a Point Merge System (in particular along, or when, entering the sequencing legs).

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- Repetitiveness hence risk of: loss of vigilance, boredom and job satisfaction issues (controllers); risk of error due to systematisation (controllers and pilots).  
→ *Potential requirements:*
  - Pilots and controllers training, awareness campaigns, and/or safety management system with monitoring of events/incidents.
- Risk of cluttering of controllers' display along sequencing legs.
- → *Potential requirements:*
  - Lateral distance between the sequencing legs.
- Risk of confusion between traffic under normal procedure and traffic under alternate procedure.  
→ *Potential requirements:*
  - System support to highlight traffic under alternate procedure (reminder, transfer, coordination).
- Controller acceptability issues: change in task allocation.  
→ *No requirement identified (other than already existing ones as per e.g. Ref[9]).*
- Subjective and operational implications of trajectory uncertainty ('long route' published and used).  
→ *No requirement identified (the same issue arises for other P-RNAV applications; besides, with Point Merge, once Direct-To the merge point, that uncertainty disappears).*
- In terminal airspace, unusual merging on a point rather than an axis.  
→ *No requirement identified (concern disappears after limited practice/exposure; there is an analogy with E-TMA practices).*
- In terminal airspace, unusual situation with legs of opposite direction vertically separated.  
→ *No requirement identified (this concern disappears after limited practice/exposure).*
- Risk of confusion over responsibility for terrain/obstacle clearance (between legs and merge point).  
→ *No requirement identified (See §12.3, actually a known P-RNAV regulatory aspect – may however need to be highlighted in training).*

#### System support

- Technical implications of trajectory uncertainty due to 'long route' being published and used.  
→ *No requirement identified (the same issue arises for other P-RNAV applications; besides, with Point Merge, once Direct-To the merge point, that uncertainty disappears).*

#### Consequences related to other performance areas

##### Route structure

- Path stretching capability and maintenance of "runway pressure" not simultaneously maximised (capacity KPA).  
→ *No requirement identified (actually showing a different trade-off rather than an issue);*
- Different constraint of applicability to highly constrained airspace due to a cone-shaped route structure (interoperability<sup>63</sup> KPA).  
→ *No requirement identified (to be addressed locally).*

##### Operating method, Human factors, System support

- No consequence identified

<sup>63</sup> Focus areas: homogeneous traffic flows, and application of global standards and uniform principles (Ref [46]).

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## ANNEXES

## 7. Annex: detailed operating method

As depicted in §5.1 above, Point Merge basically consists in combining an RNAV route, and a closed-loop vector in the form of a “direct-to” instruction to the merge point. The present section gives a more detailed description of the operating method. Two main modes are considered for this purpose: normal and abnormal.

The **normal mode** (i.e. in the absence of failures) comprises:

- A “**main flow**” for the nominal case, describing the core operating method and its main options (detailed in §7.1) for equipped aircraft;
- And “**alternative flows**” for specific variants, covering special/non-nominal cases (still normal i.e. not involving any particular failure) such as non-equipped aircraft, sequencing leg run-off or missed approach, and inducing alternative sequences of actions (detailed in §7.2).

The **abnormal mode** corresponds to exception handling or service failure cases, such as loss of RNAV capability (detailed in §7.3).

Based on the main options identified in §5.2.2 (with, or without levelling-off along the sequencing legs, and use of a single or multiple level(s)/altitude(s) for each leg), the “main flow” of the normal mode consists of the following cases:

Case	Lateral design	Vertical design	Also applicable with..	Detailed in..
<b>1A</b>	<b>Parallel</b> (overlapping or partly overlapping) sequencing legs.	<b>Level-off and single level</b> along the sequencing legs.	Dissociated sequencing legs with single level.	§7.1.1, §7.1.2
<b>1B</b>	<b>Parallel</b> (overlapping or partly overlapping) sequencing legs.	<b>Level-off and multiple levels</b> along the sequencing legs.	Dissociated sequencing legs with multiple levels.	§7.1.3
<b>2</b>	<b>Dissociated</b> sequencing legs.	<b>Unconstrained descent</b> along the sequencing legs.	Parallel (overlapping or partly overlapping) sequencing legs with ‘constrained descent’.	§7.1.4

**Table 7-1. Main variants in the operating method vs. Point Merge design options**

For each of the cases in Table 7-1 above, the steps to be performed by ATC and flight crew are detailed for a particular aircraft when it progresses from the entry to the exit of a Point Merge system. In addition, a high level scenario is provided for the first case, illustrating in a more dynamic way the application of the procedure to a sequence of aircraft (§7.1.2).

Finally, the “alternative flows” of the normal mode, as well as the abnormal mode, because they may have a more limited impact on the route structure or operating method, are defined in terms of **differences with the main flow**. When needed, specific impact on the route structure requirements and/or on steps in the procedure are complemented by ‘fall back’ procedures that may be common to various alternative flows and/or abnormal cases (§7.4).

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## 7.1 Normal mode – Main flow

### 7.1.1 Case 1A: Point Merge with level-off and single level on the legs

#### General conditions:

- **GC1** - Arrival and departure flows are strategically segregated in so far as possible;
- **GC2** - Clear indication of aircraft RNAV capability is available on CWP and/or flight strips.

#### Pre-conditions:

- **PreC1** - Aircraft equipped<sup>64</sup> with procedure loaded into FMS and flown by flight crew, with lateral navigation engaged, in accordance with ATC route clearance;
- **PreC2** - Appropriate acceptance rate(s) set for Point Merge system's entry – taking into consideration such issues as longitudinal separation, wake turbulence constraints, meteorological conditions, capacity constraints of the Point Merge system itself and at its exit, etc...
- **PreC3** - Delivery of metered traffic flow(s) in accordance with this(ese) rate(s) e.g. through an AMAN (see §12.2)<sup>65</sup>;
- **PreC4** - Traffic delivery with longitudinal separation within each inbound flow.
- **PreC5** - Aircraft stable at the defined level/altitude for each sequencing leg prior to leg's entry;
- **PreC6** - Traffic level such that path stretching is needed for some, if not all flights in the sequence, in order to integrate inbound flows;

#### Post-conditions:

- **PostC1** - Delivery of an integrated and efficient sequence, i.e. with convergence towards the following PMS exit conditions: a common lateral path, a common level/altitude or level/altitude window; appropriate inter-aircraft spacing and speed.

#### Operating method:

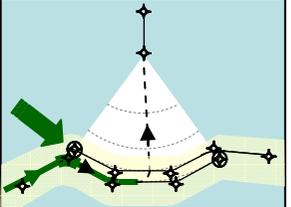
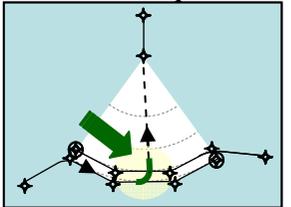
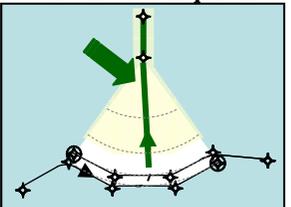
Table 7-2 below provides the high level description of the new operating method for an equipped aircraft in the normal mode, in the form of successive steps to be implemented as it progresses into the Point Merge system. It also provides a mapping onto the high level tasks identified in §3.1 above, i.e. planning, building and maintaining the sequence.

#### Notes:

1. The description of the Point Merge operating method is valid here whether the preceding aircraft in the sequence is equipped or not. This compatibility is made possible by the fact that non equipped aircraft are expected to be vectored along the normal Point Merge procedure (see §7.2).
2. Some lower level tasks or sub-tasks are not explicitly mentioned in Table 7-2, although they are expected to be implemented as today. In particular, monitoring tasks involved in various steps are not detailed, and separation assurance remains a controller task but aspects thereof that are not specific to the Point Merge operation are not explicitly mentioned in Table 7-2.
3. Finally, diagrams in the last column in Table 7-2 are only provided for illustration purpose. Although they represent a particular instance of a Point Merge system, they are not meant to specifically favour its geometry.

<sup>64</sup> i.e. 'P-RNAV approved' (see §5.4.10).

<sup>65</sup> These metering conditions may be met differently depending on the airspace and local conditions i.e. in some cases more or less systematic recourse to holding may be the nominal mean for metering.

Step	ATC	Flight crew	Notes	Phase (high level ATCO tasks)
1.	Check/confirm sequence order, before the aircraft enters the sequencing leg		This can be done by using a simple graphical tool (e.g. distance markings along the initial legs and sequencing legs) and/or with the support of an AMAN.	<b>Plan &amp; prepare the sequence</b> 
2.	Check entry conditions (altitude, speed, separation) and issue instruction as required, before the aircraft enters the sequencing leg.	Execute instruction.	Speed reduction e.g. 220kts before leg entry may be required in order to achieve homogeneous flows or to optimise the delay absorption capacity of the leg in case of high traffic load.	
3.	Monitor the spacing behind the preceding aircraft in the sequence and anticipate when the required value will be achieved.	Fly the aircraft along the sequencing leg according to the procedure (with lateral navigation engaged).	<p>The preceding aircraft in the sequence is already on course to the merge point. The monitoring of spacing can therefore be done by using a simple graphical tool (range ring centred on merge point, and/or supportive video mapping).</p> <p>Required spacing could be affected by wake vortex, weather, etc.</p> <p>Flight crew is aware of the 'direct-to' the merge point, expected to be published as guidance material alongside the procedure.</p>	<b>Build the sequence</b> 
4.	Issue Left/Right direct-to merge point when the aircraft has the required spacing behind the preceding aircraft in the sequence.	Execute the 'direct-to' the merge point (with lateral navigation engaged).	There may be situations where multiple Point Merge systems are in operation (see §9.1.2.3, §8.3). In such cases, the preceding aircraft in a particular sequence may be located in a different Point Merge system.	
5.	Issue descent clearance when clear of other traffic, and when appropriate according to altitude/level window at merge point (or at the Point Merge system exit).	<p>Manage the descent according to the clearance (with lateral navigation engaged).</p> <p>Optimise the descent, as the distance to go is known by the onboard system.</p>	<p>When issuing descent clearance, particular consideration should be given to ensure safe separation from traffic on parallel sequencing leg(s).</p> <p>Depending on Point Merge design, the descent clearance may be issued earlier (see §7.2, <i>Alternative flows</i>).</p>	<b>Maintain the sequence</b> 
6.	Use speed control to deliver the aircraft at an optimised spacing and at an appropriate speed for the exit of the Point Merge system.	Execute speed instruction(s) while flying direct-to the merge point and complying with altitude/level window at merge point, then following the procedure until its last point (with lateral navigation engaged).	<p>Again, monitoring of spacing with preceding aircraft can be done by using a simple graphical tool (range and bearing lines, range ring centred on merge point, and/or supportive video mapping).</p> <p>Required spacing could be affected by wake vortex, weather, traffic from other Point Merge system(s), etc.</p>	

**Table 7-2. Operating method: Equipped aircraft with level-off, and single level on the legs**

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Notes:

1. There is a requirement that vertical restrictions be defined and adhered to by flight crews (see §5.4), the main driver being safety (entry conditions). In addition, this will result in even less R/T exchanges and tactical instructions, better situation awareness from the flight crew perspective, and optimised vertical profile if VNAV is used. In this context, only one descent clearance may be given to the targeted level/altitude at Point Merge exit (e.g. ILS interception altitude). Nevertheless, ATC may want to successively issue intermediate clearance(s) corresponding to the published vertical restrictions.
2. Speed restrictions may also be considered (see §5.4). However, it is only a recommendation that should be confirmed for each local implementation, depending on traffic level and peak durations (trade-off between tactically releasing published restrictions when they are not needed versus explicitly issuing speed reductions when needed).

### 7.1.2 Scenario “talk-through”

This section provides an example dynamic scenario description of Point Merge application to a sequence of aircraft, for separation purposes. The structure diagram below represents a Point Merge system scenario with delivery of eastbound and westbound metered traffic flows towards two parallel sequencing legs with entry points (A & B) iso-distant from the merge point (M).

In this scenario the sequencing legs are laterally separated by 2nm and opposite direction flights are vertically separated, only one flight level/altitude being used on each leg. Aircraft remain in level flight on the sequencing legs with the outer leg nominally 1000ft below the inner leg<sup>66</sup>. The range rings between the sequencing legs and the merge point indicate 5nm intervals. Clearly, the technique described below will have been used for preceding aircraft in the sequence, but for the purposes of this scenario “talk-through”, the explanation will focus on the operational handling of the Grey, Green, Gold and Blue aircraft.

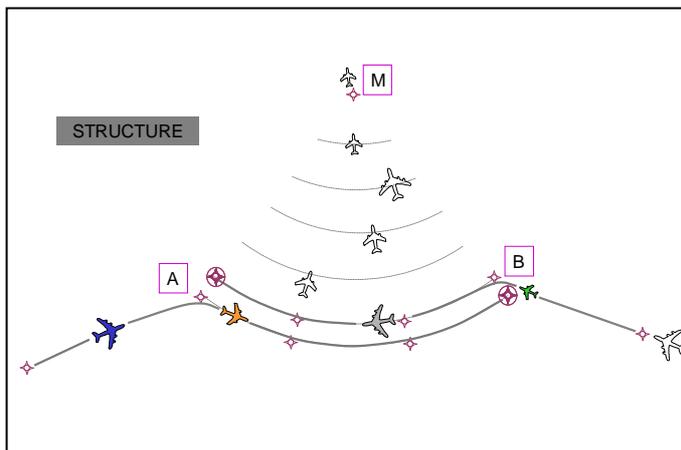
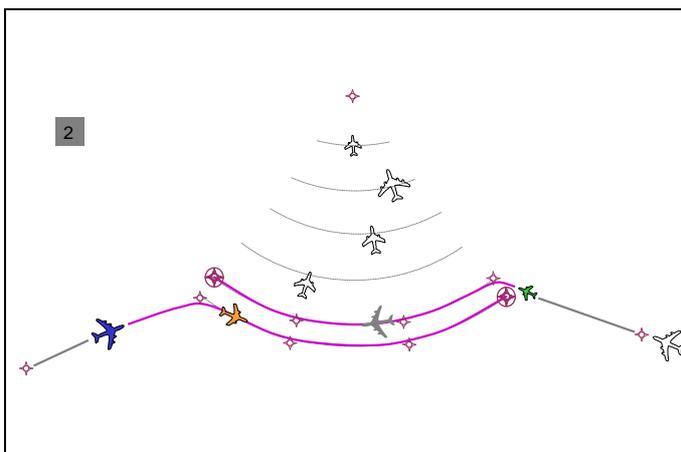
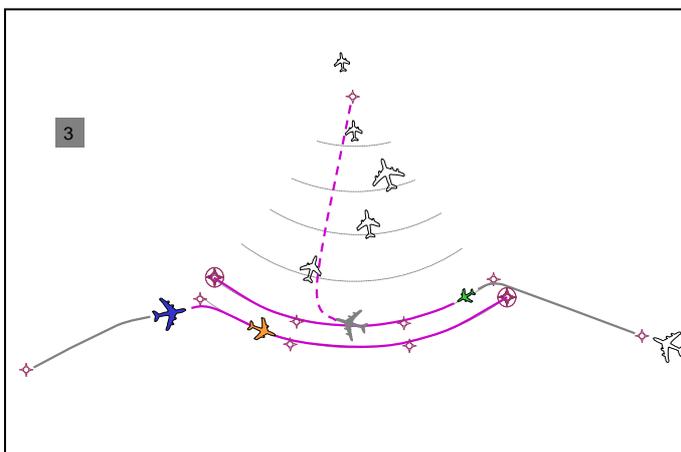


Diagram 2 shows a busy flow of traffic to the merge point with spacing based on WTC criteria for a mixed sequence of Medium (depicted by 2-engine) and Heavy (depicted by 4-engine) aircraft. The air traffic controller checks the sequence order (e.g. as provided by AMAN) and confirms that the Gold aircraft on the outer sequencing leg will follow the Grey heavy jet on the inner sequencing leg. The Gold aircraft will be followed in sequence by Green and Blue aircraft in turn. Appropriate speed control instructions to ensure separation/spacing along the sequencing legs will be implemented if and when necessary.

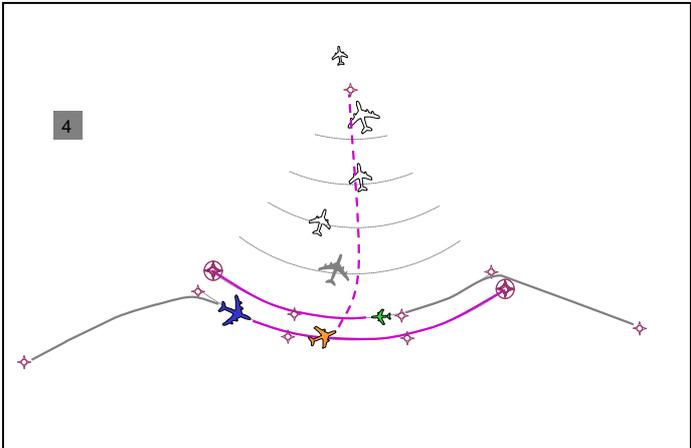


In diagram 3, when the Grey heavy jet commences the turn to the merge point, the controller determines when to issue the “direct to merge point” instruction to the Gold aircraft to ensure that the required WTC spacing behind the preceding aircraft will be achieved (although WTC spacing has to be achieved at a later stage at runway threshold, spacing maintenance and refinement relies on speed control only. Therefore, a spacing margin has to be included when issuing the direct-to instruction, accounting for WTC criteria).

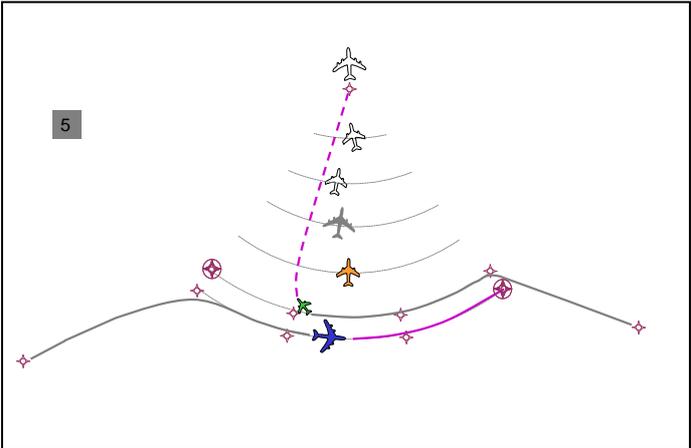


<sup>66</sup> This design choice, compared to an outer leg that would be the highest, offers flexibility and safety benefits (Cf. §8.2).

In diagram 4, the controller issues the “Turn left direct to merge point” instruction to the Gold aircraft using the range ring arcs to assess the appropriate WTC spacing from the Grey aircraft. It is important to note that in cases (such as this) where descent clearances are required following exit from the sequencing legs, particular consideration should be given to ensure safe separation from traffic on parallel sequencing legs.



The same techniques are repeated for the Green aircraft in diagram 5...



... and Blue aircraft in diagram 6.

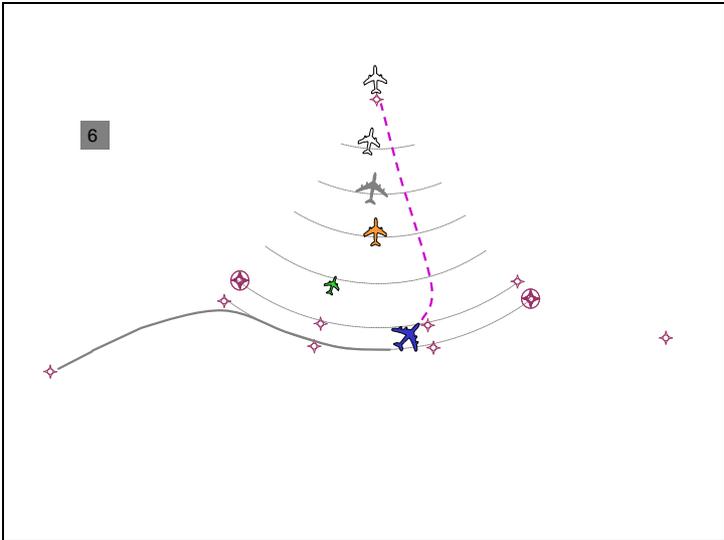
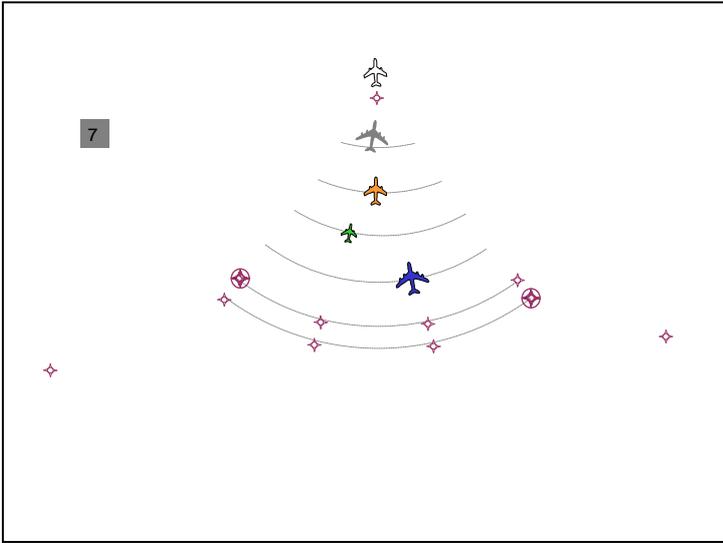


Diagram 7 shows the final appropriately constructed sequence with all aircraft proceeding directly to the merge point with appropriate spacing.



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### 7.1.3 Case 1B: Point Merge with level-off and multiple levels on the legs

<b>General conditions:</b>
----------------------------

- Same as case 1A.

<b>Pre-conditions:</b>
------------------------

Same as case 1A, except:

- **PreC5** - Aircraft stable at the appropriate level/altitude prior to leg entry *for each level/altitude used on each sequencing leg*;
- **PreC6** - Traffic delivery with longitudinal separation achieved *for each level/altitude used on each sequencing leg*.

<b>Post-conditions:</b>
-------------------------

- Same as case 1A.

<b>Operating method:</b>
--------------------------

Same as detailed in Table 7-2 above, with only an implicit difference in step 5 (descent clearance), where 'clear' of other traffic does not only refer to aircraft on other sequencing leg(s), but also those using lower level(s)/altitude(s) on the same leg.

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#### 7.1.4 Case 2: Point Merge without level-off on the legs

##### General conditions:

- Same as case 1A.

##### Pre-conditions:

Same as in case 1A, except:

- **PreC5** - *Aircraft may be in descent, within prescribed vertical windows if any, and either cleared to the Point Merge system's exit level/altitude, or to an intermediate level/altitude. In the latter case, this intermediate vertical clearance is still expected to be compatible with a flight-efficient descent profile (see operating method below).*

##### Post-conditions:

- Same as in case 1A.

##### Operating method:

Same as in case 1A except management of the descent: as there is no levelling-off constraint on the sequencing legs, aircraft can in effect be in descent at any time while flying the procedure. This is expected to enable further improvements of vertical profiles, i.e. towards advanced CDAs (see §5.2.1, §8.2.1, §9.1.2.5 and §14.2).

Step 5 in Table 7-2 is replaced by one of the following, subject to airspace and/or local constraints:

- **Single descent clearance:** as a pre-condition, a descent clearance was already issued by ATC (e.g. together with the initial Point Merge procedure/route clearance) towards flight level/altitude at Point Merge system's exit. No further vertical clearance or instruction is normally issued by ATC until the Point Merge system's exit.
- **Multiple/successive descent clearances:** as a pre-condition, a first descent clearance towards an intermediate flight level/altitude (e.g. corresponding to a published restriction at an intermediate waypoint at or before the end of the sequencing leg) was already issued by ATC (e.g. together with the initial Point Merge procedure/route clearance). One or more subsequent clearance(s), ultimately towards the flight level/altitude at Point Merge system's exit, are then issued by ATC as appropriate e.g. before actually reaching the previously cleared level/altitude. The "clear of traffic from the other leg(s)" condition as per Table 7-2, step 5 is obviously not required anymore before the vertical clearance(s).

In both cases, the flight crew may optimise the descent, subject to:

- clearances,
- any published or tactical vertical restriction (e.g. to ensure aircraft are able to descend to the Point Merge exit level/altitude even when they are sent direct-to the merge point from the leg's entry point), and
- uncertainty on the distance to go when flying along the sequencing leg; however as soon as the direct-to is issued, this uncertainty is removed and more efficient vertical profile optimisation can be achieved.

## 7.2 Normal mode – Alternative flows

Table 7-3 below provides an initial high level description of alternative modes. It may have to be completed and/or updated following further feasibility and safety assessment activities. Some cases below may be specific to the application of Point Merge in a certain category of airspace (e.g. missed approach).

Special or non-nominal case	Concerned steps (Table 7-2)	Impact on procedure, and/or alternative steps
Sequencing leg run-off	3, 4, 5, 6	In case no “direct to merge point” instruction is received when reaching the end of the sequencing leg, flight crew shall follow the sequencing leg run-off procedure detailed in §7.4.1 below.
Missed approach	All	<p>The principle is to define a missed approach procedure to be followed by the aircrew, enabling the re-integration of the aircraft in the sequence (see §7.4.2 below) in a Point Merge system feeding the runway. For this purpose, ATC will identify where to integrate the aircraft, and create an appropriate gap in the sequence.</p> <p>The missed approach procedure could bring the aircraft back to one IAF (see Figure 7-3 below). During the procedure the controllers might be able to shorten the route by re-integrating the flight in to the sequence. Alternatively the procedure could for instance bring the aircraft on a “leg” at the same distance from the merge point as the standard legs, or even at a shorter distance, easing the re-insertion task for the controllers, and limiting the penalization (in terms of extra distance to be flown) for the concerned aircraft (see Figure 7-4 and Figure 7-5 below). Use of ‘discrete holding’ could also be envisaged (see Figure 7-5).</p> <p>Depending on FMS capability, the aircraft may not be able to resume the RNAV procedure, and it may need to be vectored. Vectoring might also be used for other aircraft in the sequence in order to create the gap; however this should be a last resort solution as the Point Merge process should normally not be disrupted by a flight executing a missed approach.</p>
Emergency	All	<p>ATC identifies where to integrate the aircraft in emergency, assuming that it will be allocated a short route (e.g. direct/straight in to the merge point, to the exit of the Point Merge system or to the FAF using radar vectors if necessary), then creates an appropriate gap in the sequence.</p> <p>This may require using radar vectors for other aircraft in the sequence in order to create the gap within a short amount of time (see §7.4.3).</p>
Meteorological conditions: strong wind	1, 2, 3, 4, 6	<p>In case of strong winds, controllers may have to adapt to the situation specifically – as is already the case with current operations, in particular to:</p> <ul style="list-style-type: none"> <li>- take account of wind effect when assessing the sequence order (step 1 in Table 7-2 above), and later instructing the “direct-to” (steps 3 and 4) in case the wind has a different effect on the preceding aircraft (e.g. if it is in a different, dissociated sequencing leg);</li> <li>- compensate, through adapted speed instructions, for the differences in wind effect for aircraft flying along different sequencing legs (step 2) or while “direct-to” the merge point (step 6);</li> <li>- if necessary adopt different speed values on dissociated sequencing legs for which the wind has a different effect during the “direct-to” phase, and thus anticipate the compensation required for differences in ground speed variations when turning towards the merge point (step 2).</li> </ul>
Other meteorological conditions	To be assessed	The effect of other meteorological conditions, on the operating method, needs to be assessed. As in current procedures, capacity may need to be adjusted. In the worst cases (e.g. cumulonimbus on the merge point), it may be required to use radar vectors for the concerned aircraft (see §7.4.3).
Holding at Point Merge system entry	Pre-conditions	In case traffic demand is such that it is in excess of the Point Merge system’s capacity, and cannot be metered efficiently, holding may be required upstream of the Point Merge system (see §7.4.4). When leaving the same stack, because open-loop vectors are normally not used anymore, and aircraft are following the same route, there may be cases when vertical separation will be required. In such occasions, a spare level will be used for one of the concerned aircraft in case of parallel sequencing legs.
Low traffic demand	3, 4	In case of low traffic load, aircraft may be instructed direct to the merge point straight in before they reach the first point of the sequencing legs, subject to local constraints (e.g. segregation

Special or non-nominal case	Concerned steps (Table 7-2)	Impact on procedure, and/or alternative steps
		between arrival and departure flows).
Low performance aircraft	All	A specific procedure may have to be defined (see §7.4.5).
Non equipped aircraft	Pre-conditions,  Steps 2 to 6	<p>The pre- and post-conditions are the same as for an equipped aircraft, except that the RNAV procedure cannot be loaded in the FMS nor flown by the crew. Instead, non equipped aircraft (i.e. without P-RNAV capability /approval) shall be integrated into the sequence while achieving adherence to the normal Point Merge design through vectors along the sequencing legs, and turn (heading instruction(s)) to the merge point. Flight crews will implement these ATC instructions with lateral navigation disengaged. Non-equipped aircraft will thus follow a trajectory that operationally reflects the Point Merge RNAV procedure (see §7.4.3.2).</p> <p><u>Notes:</u></p> <ol style="list-style-type: none"> <li>1. Flight crews are required to inform ATC if they cannot accept a P-RNAV procedure for which they have been cleared.</li> <li>2. FMS capability for non equipped aircraft is <u>not</u> expected to include adherence to vertical or speed restrictions as defined in the procedure.</li> </ol>

**Table 7-3. Operating method: normal mode, alternative flows**

### 7.3 Abnormal modes

Table 7-4 below provides an initial high level description of exception handling and failure modes. It may have to be completed and/or updated following safety assessment activities. Some cases below may be specific to the application of Point Merge in a certain category of airspace.

Abnormal event or conditions	Concerned steps (Table 7-2)	Response
Traffic flow not metered according to appropriate rate(s)	Pre-conditions	Depending on traffic context, ATC may have to 1) temporarily apply sequencing leg run-off procedure (see Table 7-3), and/or 2) use radar vectoring (see §7.4.3), and/or 3) open holding stacks.
Incorrect indication of aircraft P-RNAV capability in the FDPS/on the CWP	Pre-conditions	When cleared for the procedure, flight crew notifies ATC that he cannot fly the procedure; ATC then applies the procedure for non equipped aircraft (see Table 7-3).
Degraded airborne navigation accuracy , or loss of airborne P-RNAV capability for a single aircraft	Any	Flight crew informs ATC; ATC monitors flight(s); if necessary uses radar vectors for this aircraft (see §7.4.3), and treat it as a non-equipped aircraft.
Degraded airborne navigation accuracy , or loss of P-RNAV capability for all aircraft	Any	Global reversion to vectoring. Note: this is expected to be a very rare event.
Radio failure (equipped aircraft)	Any	Flight crew follows published radio communication failure procedure for equipped aircraft (see §7.4.6).
Radio failure (non equipped aircraft)	Any	Flight crew follows published radio communication failure procedure for non-equipped aircraft (see §7.4.6).
Aircraft is suitably equipped, but does not follow the cleared procedure	Any	ATC monitors and detects non conformance. If needed uses radar vectors for the concerned aircraft (see §7.4.3) and treat it as a non-equipped aircraft.
Aircraft does not enter the leg at correct altitude.	2	ATC re-issues altitude instruction or uses spare level, ultimately vectors aircraft off the leg for separation.
Aircraft does not reduce speed (or is not instructed to do so) or reduces speed too late (or is instructed too late)	2	ATC re-assesses and if necessary changes sequence order; in case of too tight spacing, ATC may use vertical separation (e.g. spare level on parallel sequencing legs) or radar vectors (see §7.4.3) for the concerned aircraft.
Late sequence change is needed	3, 4, 5, 6	Sequence order is nominally decided before instructing the “direct-to” the merge point. In exceptional cases (e.g. emergency, aircraft not following a descent instruction) a late sequence change might be required. The response will generally involve the use of radar vectors for aircraft concerned with this change (see §7.4.3).
Aircraft does not turn to the merge point (or is not instructed to do so) or turns too late to the merge point (or is instructed too late)	4	ATC re-assesses and if necessary changes sequence order; if needed applies sequencing leg run-off procedure or uses radar vectoring for concerned aircraft (see §7.4.3) so as to re-integrate the flight in the sequence.
Aircraft turns too early to the merge point (or is instructed too early)	4	ATC re-assesses and if necessary changes sequence order; in case of risk of separation infringement, or too tight spacing, ATC may use radar vectors (see §7.4.3) for the concerned aircraft.
Wrong aircraft turns to the merge point (or wrong aircraft is instructed)	4	Subject to traffic load conditions and spacing with preceding aircraft in the sequence, use radar vectors (see §7.4.3).
Aircraft does not descend as expected, i.e. descends without being instructed, or descends too late (or is not instructed to descend when appropriate)	5	- If descent is initiated too early (i.e. without being instructed to do so), radar vectors (see §7.4.3) may be needed to ensure separation with traffic from other sequencing legs; this may in turn trigger changes in the sequence. Note: this may actually not be an issue if the inner sequencing leg is designed the highest – in case of parallel sequencing legs.

Abnormal event or conditions	Concerned steps (Table 7-2)	Response
		- If descent is initiated too late, radar vectors may also be needed so as to make sure aircraft will be able to descend; this may in turn trigger changes in the sequence as well.
Aircraft does not reduce speed (or is not instructed to do so) or reduces speed too late (or is instructed too late)	6	In case of too tight spacing, ATC may use radar vectors for the concerned aircraft (see §7.4.3).
Impossibility to maintain spacing through speed control (e.g. initial spacing with preceding aircraft created by the 'direct-to' instruction not including sufficient margin with respect to available speed range to maintain spacing).	6	Use radar vectors for the concerned aircraft (see §7.4.3), and re-insert it in the sequence – if possible before the merge point.

**Table 7-4. Operating method: abnormal modes**

Note: when using vectors for an aircraft concerned with an exception or failure, it may be necessary to re-assess the sequence behind it, possibly resulting in speed actions for flights already on course towards the Merge Point, a later turn for the ones still flying along the legs or even in some cases radar vectors.

## 7.4 Associated fallback procedures

This section details possible fall-back procedures corresponding to various situations mentioned above in §7.2 (alternative/non nominal cases) or §7.3 (abnormal cases/exception handling), where deviation from the normal Point Merge procedure becomes necessary.

### 7.4.1 Sequencing leg run-off

Aircraft flying a Point Merge procedure are not expected to use nominally the full length of the sequencing legs. However in order to cater for certain non nominal cases, a specific ‘sequencing leg run-off’ procedure needs to be defined.

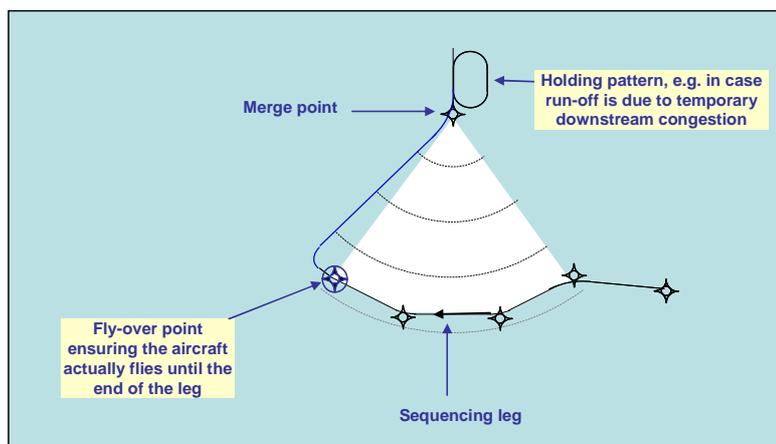
The recommended generic procedure is depicted in Figure 7-1 below. It consists in continuing the route by automatically turning towards the merge point and maintaining the level/altitude used along the legs (or descending according to ATC clearances and published vertical restrictions if any).

This makes Point Merge a closed procedure.

ATC may then:

- Clear the aircraft for the descent and adjust speed as described in steps 5 and 6 in Table 7-2;
- Or:
- Delay descent and instruct the aircraft to maintain current level;
- Optionally (may not be suitable to all environments) instruct the aircraft to hold (e.g. just after the merge point), until it can be re-integrated in the sequence.

Similarly to the use of radar vectors to recover from unexpected situations, this procedure also allows the controller to visually distinguish the ‘problem aircraft’ from the other aircraft in the sequence.



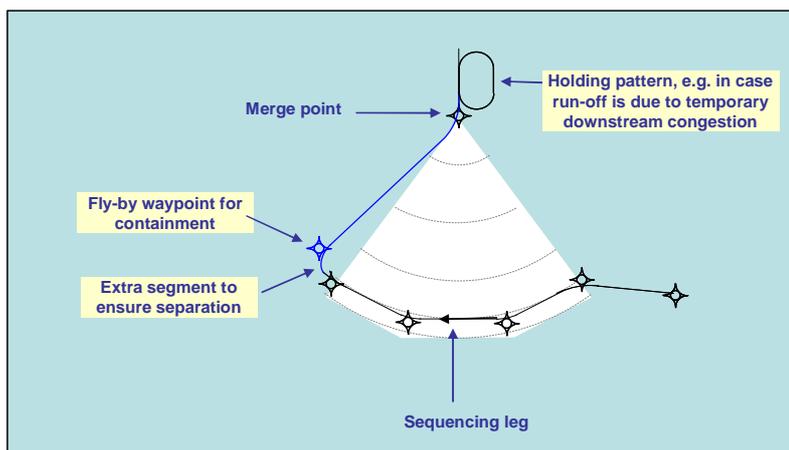
**Figure 7-1. Sequencing leg run-off procedure (fly-over)**

As illustrated above, it is recommended using a fly-over waypoint as the final waypoint on the sequencing leg, followed by a ‘Computed track Direct to a Fix’ (DF) path terminator (see Ref[10]) to the merge point so as to enable keeping the aircraft on the leg up to this final waypoint, providing the controller with unambiguous turning point and ensuring maximum time to manage the traffic (Ref [24]).

#### Notes:

1. In order to achieve the required level of metering at the Point Merge system’s entry (so as to avoid too frequent sequencing legs run-off), it is recommended that an adequate sequencing support tool (e.g. an AMAN) be used. Nevertheless, the need to delay one or more aircraft longer than what can be achieved with the Point Merge procedure may be due to an unexpected downstream capacity issue – e.g. a temporary runway closure. In that case, an alternative solution could be, instead of letting aircraft fly the run-off procedure and possibly hold just after the merge point, to vector aircraft reaching the end of a leg directly to the hold located before the entry of the opposite direction leg, or to a pre-defined, discrete holding (see §7.4.4).

2. Alternative designs might be envisaged, such as using an additional fly-by waypoint after the last point of the leg to ensure trajectory containment when turning direct-to the merge point (Figure 7-2). This solution may offer the advantage of better trajectory containment in case of sequencing leg run-off.
3. Finally, with or without such a pre-defined sequencing leg run-off procedure, controllers may manage the occurrences of sequencing leg run-off through tactical instructions (e.g. maintenance of current heading at the end of the leg, possibly subsequent vectoring, and then resuming the procedure through a direct-to the merge point when required inter-aircraft spacing is achieved).



**Figure 7-2. Sequencing leg run-off procedure (fly-by)**

#### 7.4.2 Missed approach

This procedure is specific to the application of Point Merge in Approach.

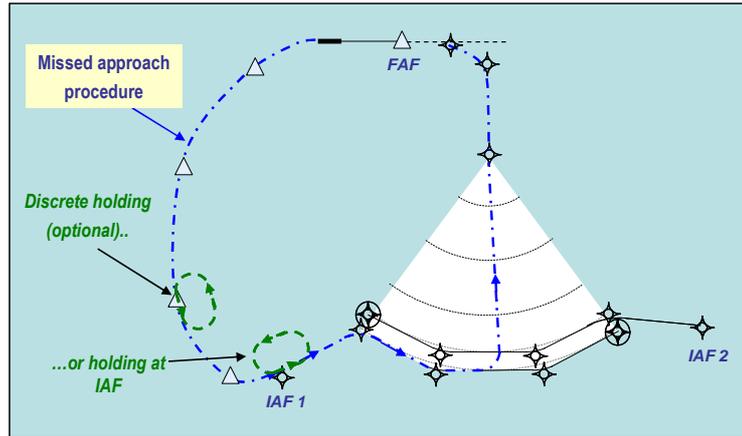
Currently, missed approaches are designed as conventional procedures. In the case of Point Merge, the missed approach may be conventional (for both non-equipped and equipped aircraft), with radar vectoring to place the aircraft back into the arrival stream (Ref [24]). Alternatively, the operation may envisage the Point Merge system with lateral navigation to be re-used following a missed approach (for equipped aircraft only), in which case it should be recognised that it will be necessary to reload the arrival procedure in the FMS.

The missed approach procedure should provide an easy reintegration in the Point Merge system. Subject to local operational or environmental constraints, including the dimensions of the Point Merge system, the procedure may bring the aircraft back at different locations, more or less close to the merge point, i.e. to:

- (Option 1 below) the IAF; or
- (Option 2 below) a pseudo sequencing leg – at the same location as the sequencing leg, but possibly using a different level/altitude; or
- (Option 3 below) an inner pseudo-sequencing leg – located inside the Point Merge ‘triangle’, respecting the equidistance property to the merge point.

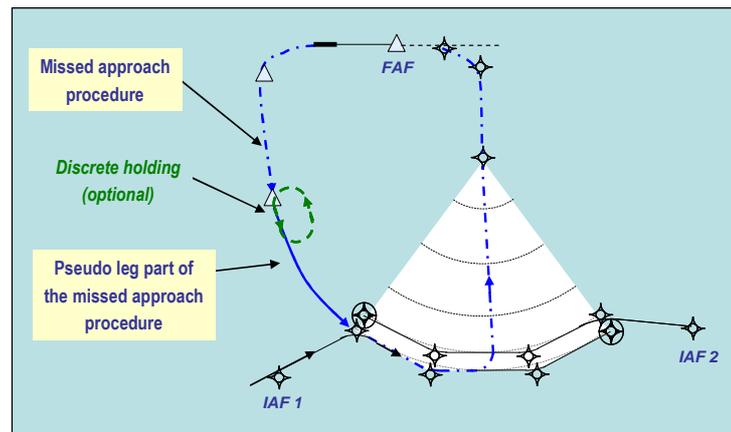
In any case, the missed approach procedure involves the creation of a gap in the sequence, hence delaying other flights. Using an existing or discrete holding area, so as to re-insert an aircraft in the sequence when possible after a go-around, would minimise the delay on other flights.

Option 1: the procedure brings the aircraft back to the IAF. Optional holding may be envisaged at the IAF or at a discrete holding before reaching the IAF, along the procedure. This option may result in a long distance flown before re-integrating the approach procedure, with an impact on fuel consumption – although vectoring (see §7.4.3) remains possible at any time for early re-insertion into the sequence (with appropriate co-ordination). It might also not be suitable in a high density environment (due to more interactions with other flows, or with segregated areas).



**Figure 7-3. Missed approach, option 1: back to Initial Approach Fix**

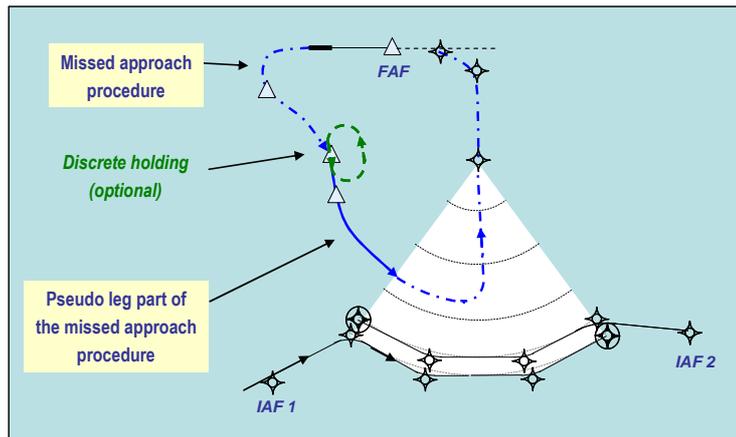
Option 2: the procedure brings the aircraft back to a point where the trajectory will follow a “pseudo-leg” at the same distance as the standard one, partly eliminating the drawbacks of option 1 above. The procedure would allow joining one sequencing leg or the other (the altitude/level assigned for the missed approach will ensure vertical separation). Re-integration into the sequence would be easier. However option 2 may require the use of additional levels e.g. below the actual sequencing legs, which could induce operability issues (possible altitude/level confusion) or applicability issues (availability, and use, of additional and spare levels).



**Figure 7-4. Missed approach, option 2: back to a “pseudo-sequencing leg”**

Option 3:

Alternatively, as a variant for option 2, and actually the preferred option when feasible, it may be envisaged to join an inner ‘pseudo’ sequencing leg, i.e. parallel to the sequencing legs and inside those, resulting in an even shorter procedure:



**Figure 7-5. Missed approach, option 3: back to an inner “pseudo-sequencing leg”**

### 7.4.3 Use of radar vectors

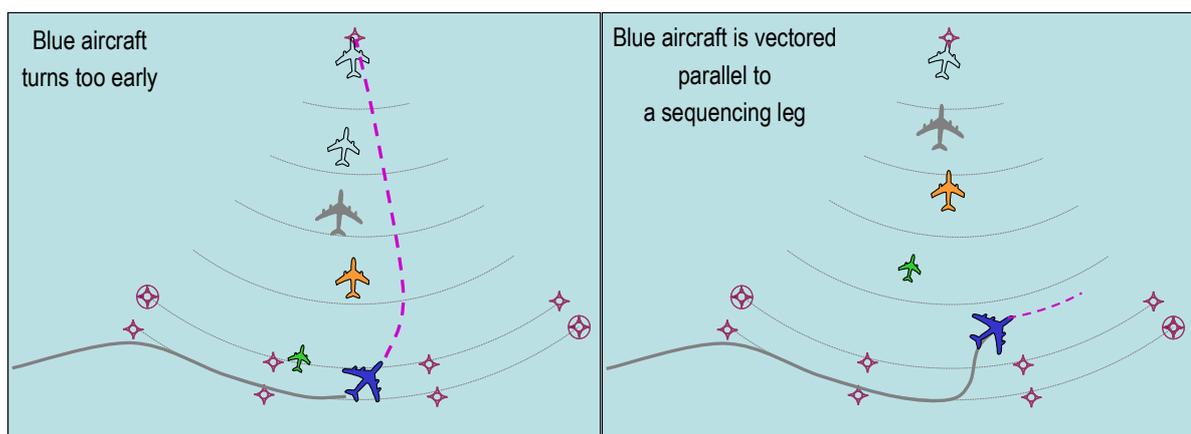
Radar vectors may be used in order to recover from unexpected situations, or for non equipped aircraft.

#### 7.4.3.1 Recovery from unexpected situations

In order to recover from a variety of unexpected situations, as explained in §7.2 and §7.3 above, it may be necessary to use radar vectors for one or more otherwise suitably equipped aircraft in the sequence, for a limited period of time. The general principle in that case is to avoid global reversion to vectoring in so far as possible. For this purpose the following two steps shall be followed:

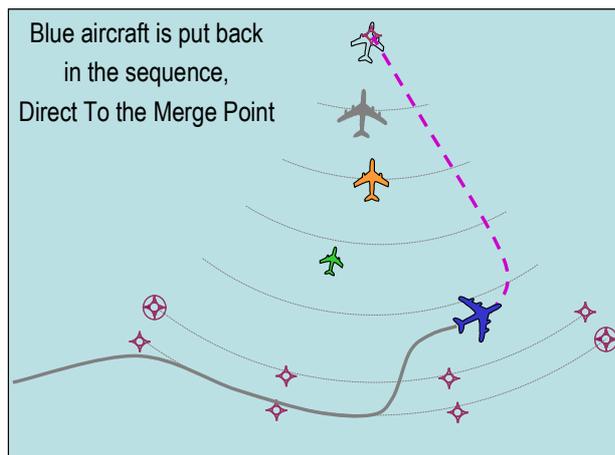
1. Put the concerned aircraft out of the sequence and vector it/them by following a path parallel to the sequencing leg i.e. using a ‘virtual’ inner sequencing leg, at an appropriate level/altitude (given level/altitude requirements at the merge point and distance to go);
2. When appropriate (i.e. when the required spacing with the preceding aircraft in the sequence is reached), put it/them back into the sequence, by issuing the ‘direct-to’ instructions to the merge point.

Applying this technique ensures compatibility with traffic under the normal procedure; it also allows the controller to visually distinguish the ‘problem aircraft’ from the other aircraft in the sequence. Figure 7-6 to Figure 7-8 below show such an example after ‘blue aircraft’ turned too early towards the merge point, behind ‘green aircraft’.



**Figure 7-6. Use of vectors: aircraft turns too early**

**Figure 7-7. Use of vectors: aircraft is vectored along a ‘pseudo sequencing leg’**



**Figure 7-8. Use of vectors: aircraft is put back into the sequence**

#### 7.4.3.2 Non equipped aircraft

As stated in Table 7-3 above, non equipped aircraft “will be integrated into the sequence while achieving adherence to the normal Point Merge design through vectors along the sequencing legs, and turn (heading instruction(s)) to the merge point”. It should be remarked that:

- While equipped aircraft follow a ‘STAR-based’ CDA in a Point Merge system, a ‘radar-based’ CDA (i.e. with provision of DTG estimates by ATC – see Ref [14]), may be carried out with non-equipped aircraft.
- Non-equipped aircraft will not adhere to speed or altitude/FL restrictions as published in the Point Merge procedure.

**Note:** Among safety requirements or recommendations identified from initial safety assessment, the following ones are relevant to the case of non equipped aircraft:

In order to minimise the risk of confusion when using radar vectors in a Point Merge environment:

- The CWP shall offer the possibility to highlight aircraft that are not on lateral navigation (e.g. being on a heading towards the merge point);
- Clear handover procedures – and contingency procedures (e.g. in case of RNAV loss) – shall be defined so as to avoid confusions in the event of one or more aircraft being vectored towards the merge point when they are transferred (instead of being under lateral navigation, on a direct track to that point).

**Note:** As for any P-RNAV procedure, ATC shall ensure that instructions are given which prevent aircraft capturing a path other than expected when rejoining the Point Merge procedure after being vectored.

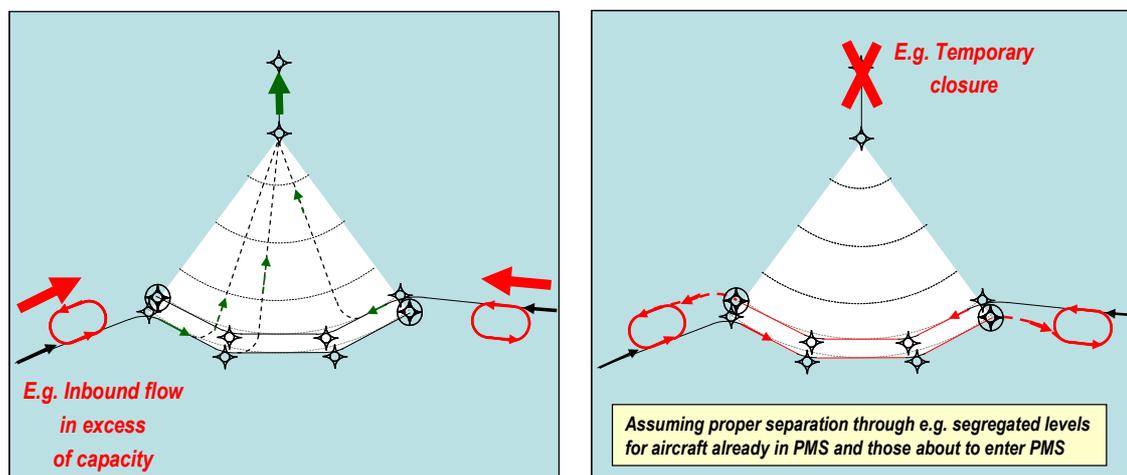
#### 7.4.4 Holding

The Point Merge procedure provides a structured way of implementing path stretching for delay absorption, but is not aiming at replacing holding stacks. Therefore, in addition to (and irrespective of) specific discrete holding options as depicted above, holding stacks shall be established before the sequencing legs to cater for e.g. traffic peaks beyond upstream traffic metering capability, missed approaches and LVP operations. Where possible, the holds should be positioned to:

- Feed the aircraft onto the sequencing legs (e.g. having the lowest level of the holding identical to the sequencing leg entry level or 1000’ above), and
- When needed, in case of parallel legs of opposite direction, allow ATC to vector an aircraft reaching the end of the opposite direction leg directly to the hold, in the event of a temporary runway closure, for example (see Ref [24]).

Furthermore, in order to ensure that aircraft properly enter the sequencing legs when leaving the stacks (i.e. avoid overshoots), the latter should be located at a sufficient distance upstream from the legs entry points. This may justify the need for an initial route segment before the sequencing leg.

Figure 7-9 below provides an example of holding stacks designed prior to the sequencing legs in order to accommodate either a situation where the inbound flows temporarily exceed the Point Merge system capacity (left hand side diagram), or the ‘worst case’ where aircraft flying along the sequencing legs have to eventually hold as well, due to a shortage in downstream resources (right hand side diagram – e.g. temporary runway closure)<sup>67</sup>.

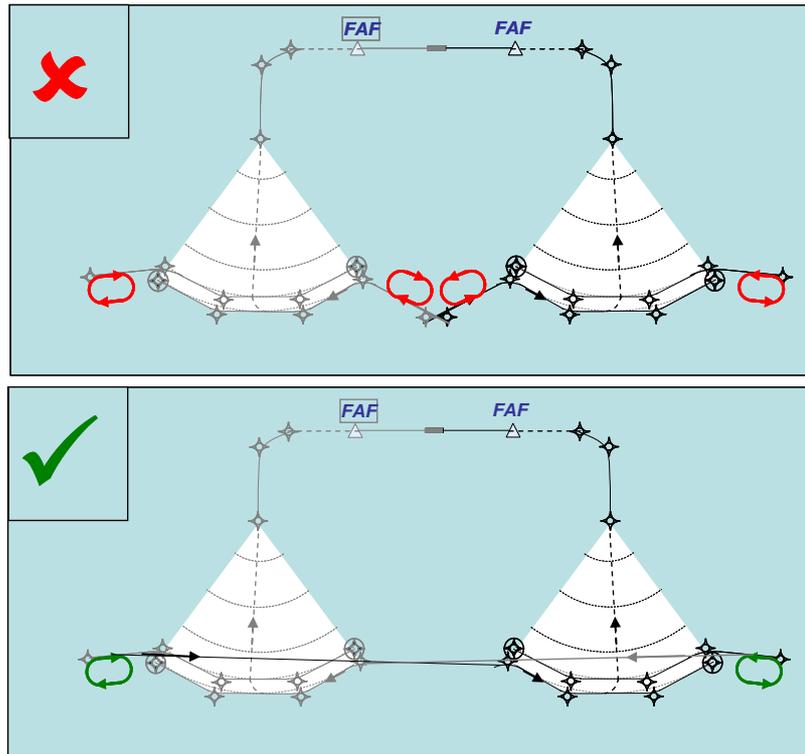


**Figure 7-9. Use of holding stacks according to operational context (example)**

Notes:

1. There is currently no provision for specific holding criteria in P-RNAV procedures, therefore holds may be designed either conventionally or as RNAV holds.
2. A holding stack may also be defined before the exit of the Point Merge system, before, at or after the merge point; such a discrete holding would allow for instance to deal with situations where a particular aircraft cannot be kept in the sequence anymore, or in case of runway closure, without having to systematically send it back to upstream holding stacks. More details and examples are available from §7.4.1, §7.4.2 above.
3. Ref [9] Part C, §5.4.3 recommends that “[H1.3] to the extent possible, the location of holding patterns should remain constant, irrespective of the runway in use”. As the location of Point Merge systems in approach will generally be dependent from the runway in use, this implies that it may not be always possible to feed directly the aircraft onto the sequencing legs from all holding stacks, due to long downwind legs between the holding stack and the sequencing leg entry point (Figure 7-10). Nevertheless, in that case it is expected that part of the sequencing leg capacity can be used to compensate for the lack of accuracy when leaving the stack.

<sup>67</sup> In case of parallel legs of opposite directions, the use of a hold to cater for aircraft reaching the end of the opposite leg (e.g. in the event of a temporary runway closure as depicted in Figure 7-9) should be envisaged as a marginal solution, limited to a few aircraft, as traffic will continue to arrive through the PMS entry point feeding the same hold.



**Figure 7-10. Location of holding stacks**

#### 7.4.5 Low performance aircraft

In case the traffic includes low performance aircraft (e.g. slow aircraft / general aviation), it may be necessary to locally define a specific procedure to integrate such aircraft in the sequence (i.e. specific routes, or lower flying aircraft to be integrated later in the sequence e.g. upon approaching the merge point, or beyond that point for integration along the ILS axis). Low performance aircraft that are not P-RNAV approved would then have to be vectored along the specific procedure.

Formally, this means that ATC could then have to deal with a number of different cases, as shown by Table 7-5 below:

Aircraft performance	Aircraft equipage	Procedure
'Standard'	P-RNAV approved	Nominal Point Merge procedure
'Standard'	Non P-RNAV approved	Vectors along the nominal Point Merge procedure
'Low'	P-RNAV approved	Alternative Point Merge procedure for 'low performance' aircraft
'Low'	Non P-RNAV approved	Vectors along the alternative Point Merge procedure for 'low performance' aircraft

**Table 7-5. Possible combinations of aircraft performance levels and P-RNAV equipage**

This may become an operability and human factors issue in case of a significant proportion of low performance and/or non P-RNAV approved aircraft. However, in practice, it is not expected to be the case at main airports.

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#### **7.4.6 Radio failure**

The sequencing leg run-off procedure detailed in §7.4.1 above shall be the basis for the radio failure procedure for equipped aircraft. This radio failure procedure should in addition contain some guidance for the descent (e.g. in the form of level restrictions embedded in the procedure). The recommended use of a fly-over waypoint as final waypoint of the sequencing leg will also provide the controller with an unambiguous turning point while ensuring maximum time to manage the traffic (Ref[24]).

For non equipped aircraft, a radio failure procedure shall be defined, relying on conventional navigation aids, taking account of local constraints, while minimising interferences with the aircraft following the P-RNAV procedure. This has to be defined on a case-by-case basis.

## 8. Annex: Detailed route structure options

This section describes as extensively as possible the possible variations in the design of a Point Merge system, as well as their expected impact on applicability, feasibility and performance aspects.

Design options are categorised below into three groups:

- The key **dimensioning parameters** of a Point Merge system (§8.1);
- The main **geometrical characteristics** of a Point Merge system (§8.2);
- The possible **combinations of Point Merge systems** into a route structure (§8.3).

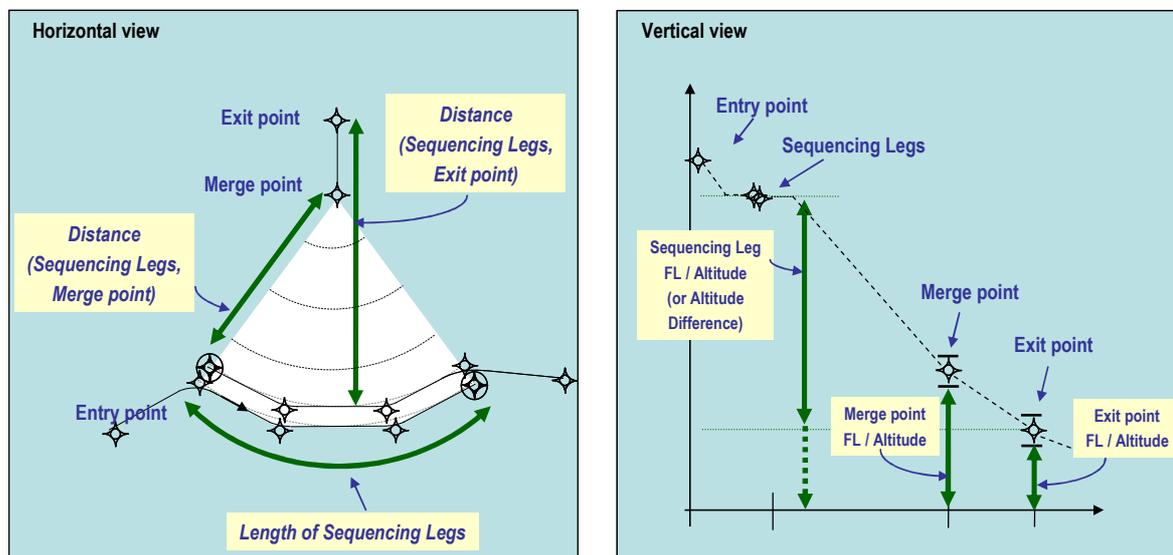
Each possible solution, involving a particular set of choices for these options – considering a given airspace configuration – may have its own advantages and drawbacks, without prejudice to the operating method's underlying principles.

### 8.1 Dimensioning parameters

Key Point Merge system parameters include:

- The length of the sequencing legs;
- The distance between the sequencing legs and the merge point;
- The distance between the sequencing legs and the last point of the procedure;
- *Note: considering variations of this distance independently from the distance to the merge point means that the distance from the merge point to the exit point varies;*
- The altitude(s)/level(s) of the sequencing legs<sup>68</sup> (or at the entry of the Point Merge system), and/or the difference with the level/altitude window at the exit of the Point Merge system;
- The altitude/level window of the merge point.

Figure 8-1 shows these parameters in the case of parallel sequencing legs with level off.



**Figure 8-1. Key dimensioning parameters**

Table 8-1 below shows the impact of variations in these dimensioning parameters.

<sup>68</sup> Figure 8-1 represents a Point Merge system with close parallel sequencing legs, with the design choice of flights being level along these legs. As stated in §7.2, the use of dissociated sequencing legs is expected to enable to release the vertical separation (or level-off) constraints.

Parameter variation	Benefits	Drawbacks
Increasing the length of the sequencing legs	- Increased delay absorption capacity (aircraft being able to remain longer on the legs)	- With segmented sequencing legs (see §8.2 below) longer sequencing legs may result in increased sensitivity to wind, which effect may be different on each segment.  - Larger 2D footprint
Increasing the distance between the sequencing legs and the merge point	- Facilitation of the maintenance of the spacing through speed control, and better spacing accuracy at the merge point, hence also beneficial in terms of operational acceptability of the procedure.  - Direct-to less time critical as there is more opportunity to compensate/refine spacing through speed control while on course to the merge point.  - Sequence being built early, increased predictability.	- Sequence being built early, decreased flexibility in sequence changes (without using vectors) in particular: may raise sequence re-integration issues with less ability to fill gaps in the sequence e.g. missed approach, late direct to.  - Larger 2D footprint and higher level/altitude for the legs.
Increasing the altitude of the sequencing legs	- Decreased environmental impact and increased flight efficiency (portions of trajectories involving larger dispersion will be flown at higher altitudes).  - Combined with an increase in the distance between the sequencing legs and the exit point, it will also enable continuous descent (CDA) from higher altitudes/FLs.	- May require to also increase the distance between the sequencing legs and the merge points, with drawbacks as stated above.  - Higher legs will have to be flown faster, resulting in less delay absorption capacity for the same length.  - May raise issues related to heterogeneous aircraft performances.

**Table 8-1. Impact of variations in Point Merge system dimensions**

Regardless of the above, it shall be remarked that the size of a Point Merge system is expected to be limited by the following constraints (refer also to applicability aspects in §9.1.1 below):

- The size of the available airspace volume;
- The fact that the procedure shall be designed “with a vertical profile that allows for differing aircraft types/masses and atmospheric conditions” (Ref [14]).
- Airspace sectorisation and boundaries: a Point Merge system that would extend across several sectors would obviously raise ATC operational issues;

## 8.2 Geometrical characteristics

The main design options identified in §5.2 relate to the following characteristics:

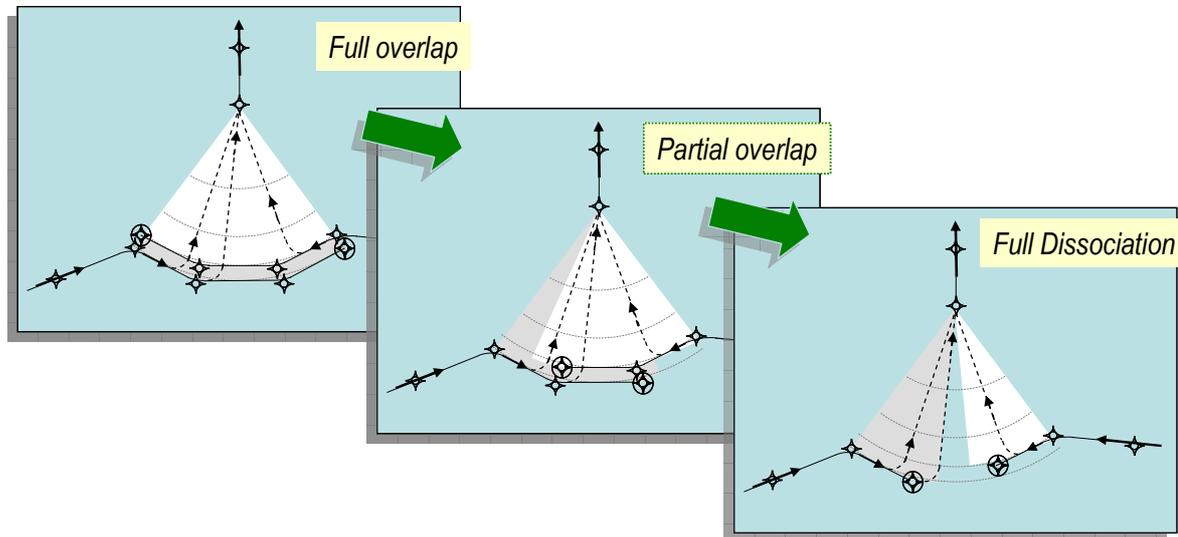
- The relative position of the sequencing legs in the horizontal plane (parallel, closely grouped or dissociated, same or opposite/alternate direction);
- The number of levels used per leg.

Further Point Merge systems geometrical characteristics are mainly depending on:

- The relative position of the sequencing legs in the vertical plane;
- The shape of the sequencing legs (straight legs, or segments closer to arcs of circle);
- Fixed, pre-defined turning points on the sequencing leg for route changes instead of immediate direct-to instructions;
- The number of sequencing legs;
- Angles and symmetry in a Point Merge system.

### 8.2.1 Relative horizontal position of the sequencing legs

As detailed in §5.2, the sequencing legs may be parallel with full overlap, parallel with partial overlap, or dissociated. Figure 8-2 below shows corresponding variations in the route structure, considering different path stretching capabilities, with similar lateral dimensions for the global lateral envelope of possible paths.



**Figure 8-2. Dissociation by adjusting the length of the legs**

### 8.2.2 Use of multiple levels/altitudes on a sequencing leg

Notwithstanding the need for a spare level, section 5.2 above identified as the second main design option the use of more than one level/altitude on a single leg, in case of sequencing legs with level-off. This may for instance enable dealing with local traffic delivery conditions where longitudinal separation is not achieved and vertical separation needs to be used within each inbound flow.

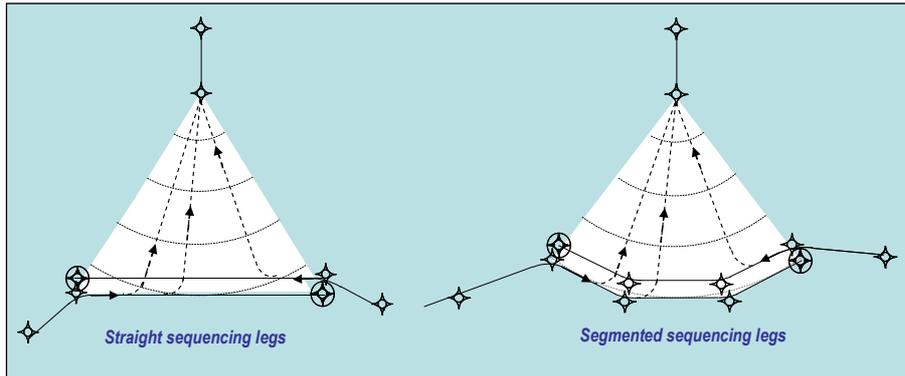
In terms of procedure definition, this option may require the definition of a distinct STAR, with its own specific vertical restrictions, for each level/altitude used on a leg.

Note that using multiple levels on a sequencing leg would not diminish in any way the need for an overall metered delivery of inbound flows (to ensure that the Point Merge system's capacity is globally not exceeded – see §12.2).

### 8.2.3 Shape of the sequencing legs

The closer the sequencing legs to arcs of circle (Figure 8-3 below), the easier it will be for the controllers to achieve an accurate initial spacing, which will in turn be beneficial in terms of acceptability of the procedure and spacing accuracy. The most natural design is segmented sequencing legs, approximating an arc centred on the merge point.

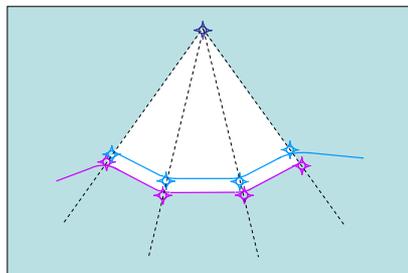
Note: historically, the first versions of Point Merge used straight sequencing legs. This was found insufficiently accurate as the distance variation to the merge point between the middle and extremities of the leg was in the order of the required spacing.



**Figure 8-3. Straight vs. segmented sequencing legs**

Notes:

1. Segmented sequencing legs involve the use of fly-by points along the leg, defining the segments.
2. Waypoints defining segments on distinct parallel, segmented legs are necessarily aligned on radials to the merge point, as shown in Figure 8-4 below.

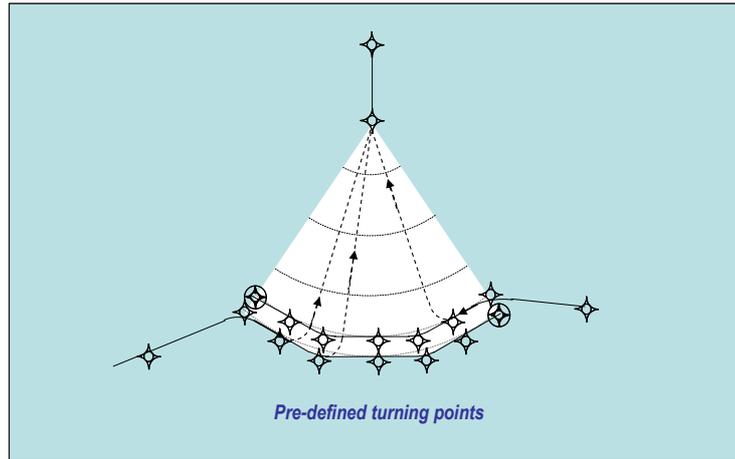


**Figure 8-4. Radial alignment of waypoints for parallel segmented legs**

3. In case of segmented sequencing legs, according to Ref [24], “careful consideration to the maximum anticipated wind should be given when calculating the minimum leg length for a particular aerodrome”. Ref [24] further states, in the case of Point Merge application to Approach, that “taking into account various track angle changes resulting from turns in case of a segmented sequencing leg, and worst case tailwind conditions, the minimum length of a sequencing leg segment should be 5NM, and leg segment length of 10NM would seem to be optimal given the need to keep chart clutter to a minimum”.
4. Although Point Merge does not rely on Required Navigation Performance (RNP) capability, it could take advantage of some of its features. For instance, fixed radius turn capability may ultimately enable designing the sequencing legs as arcs of circle, which would result in an increased inter-aircraft spacing accuracy, and fewer points stored in the database (and actually fewer points displayed to the aircrew). However this would not be compatible with path shortening techniques involving a direct to intermediate points along segmented legs (i.e. joining the leg after its entry point). Such techniques, although they would depart from the standard Point Merge working method, could be envisaged when needed in certain local implementations.

**8.2.4 Pre-defined turning points**

The use of pre-defined turning points on the sequencing legs (Figure 8-5 below) will involve a different operating method, result in a better predictability, and would pave the way towards the application of “full” RNAV routes (pre-defined turning points may ultimately characterise a set of pre-defined routes); however it would also be less flexible and less accurate than “direct-to” instructions that could be issued at any time while on the sequencing legs and could thus involve a decrease in acceptability of the operating method.



**Figure 8-5. Pre-defined turning points**

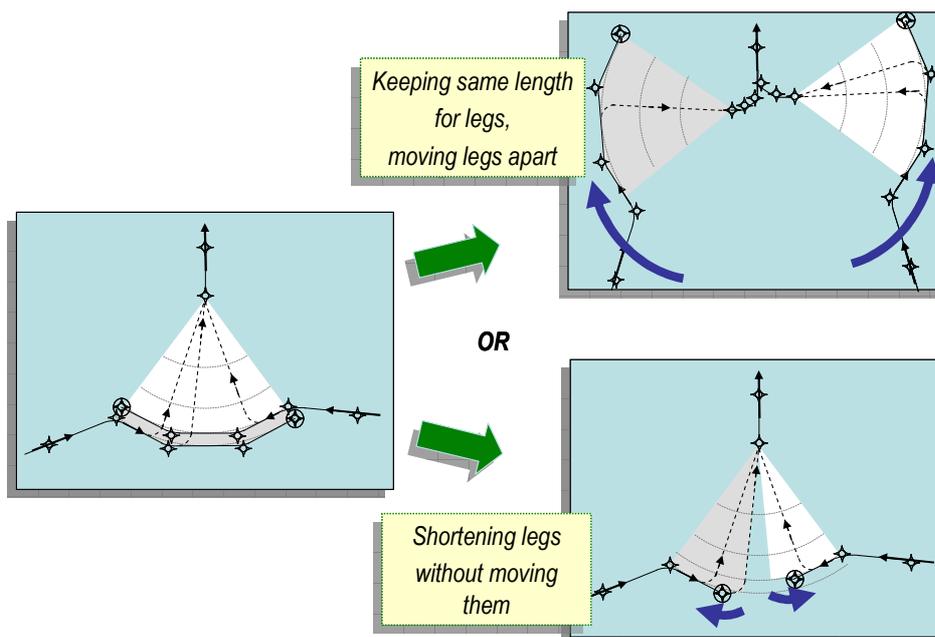
**8.2.5 Options for transitioning from parallel to dissociated legs**

Considering a configuration with parallel sequencing legs, transitioning towards fully dissociated legs may be achieved by ‘moving’ the legs apart, eventually providing sufficient lateral separation at the end of the legs, while keeping their length unchanged and maintaining equidistance to the merge point. However this type of transition will result in an increased airspace need, which may make it difficult to apply in a constrained environment. Such configuration of sequencing legs may also result in an increased sensitivity to perturbations (as the wind effect will be different on each leg when fully apart), and a difficulty to optimise the initial segments feeding the sequencing legs.

Another option is to dissociate by reducing the length of the sequencing legs without moving them apart (as already shown in Figure 8-2 above), while containing trajectories within the same global envelope of lateral paths and possibly keeping the same location for legs entry points. In that case, the path stretching capability (hence the capacity of the Point Merge system) is reduced and more stringent metering conditions will need to be applied upstream.

Note: in such configurations, an appropriate lateral separation is required between the end points of the sequencing legs – unless, again, vertical separation is considered between overlapping parts of the legs.

Figure 8-6 below shows these two options:



**Figure 8-6. From parallel sequencing legs to dissociated legs**

### 8.2.6 Options for the deployment of Point Merge route structures

Different route structures supporting Point Merge could be used, in order to fit with capacity requirements/traffic density, and subject to local constraints:

- Either in a ‘static’ manner according to the expected maximum local traffic density – typically short, dissociated sequencing legs could be deployed permanently in a medium density airspace where the extent of path stretching is expected to be limited (and/or where an appropriately efficient traffic metering/pre-regulation can be implemented);
- Or dynamically to cope with variations in traffic demand at/outside peak hours – e.g. in the same airspace, short/dissociated legs could be used outside busy periods, and longer/parallel sequencing legs during peaks of traffic, when extended path stretching is required to integrate the arrival flows;

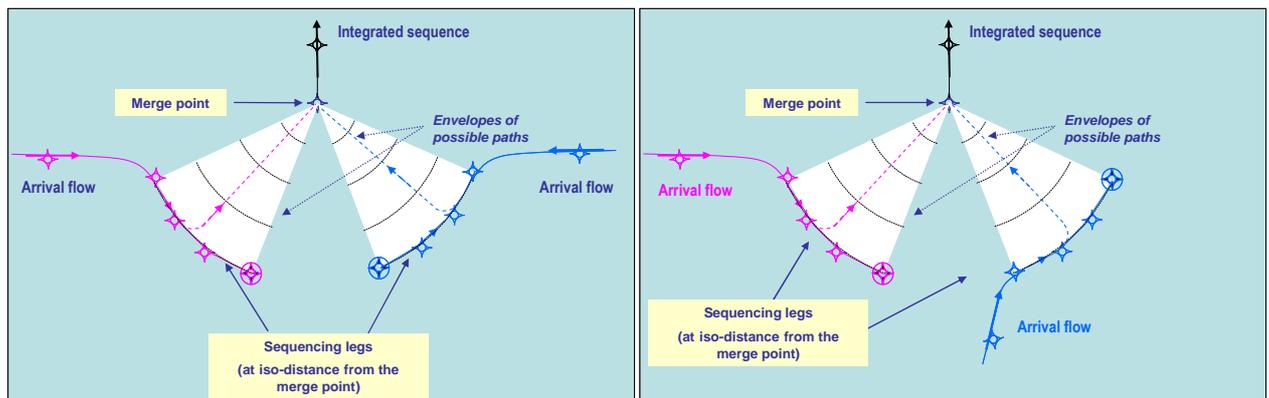
Note: dynamic deployment aspects for Point Merge would fit in the concept of airspace configuration and Terminal Airspace structures as introduced in the “2015 Airspace strategy for the ECAC Area” (Ref [7]).

### 8.2.7 Direction of sequencing legs

Sequencing legs of same direction may enable accommodating specific configurations involving the merging of more than two inbound flows with parallel sequencing legs (see §8.2.9 below).

Dissociated legs may also be of same or opposite direction. Figure 8-7 below provides other examples of Point Merge systems dealing with two inbound flows and comprising two sequencing legs that are:

- Dissociated and of opposite directions (left hand side diagram) or same direction (right hand side diagram);
- Segmented, approximating arcs of a circle centred on the merge point (iso-distance requirement).



**Figure 8-7. Dissociated sequencing legs of opposite or same directions**

### 8.2.8 Relative vertical position of the sequencing legs

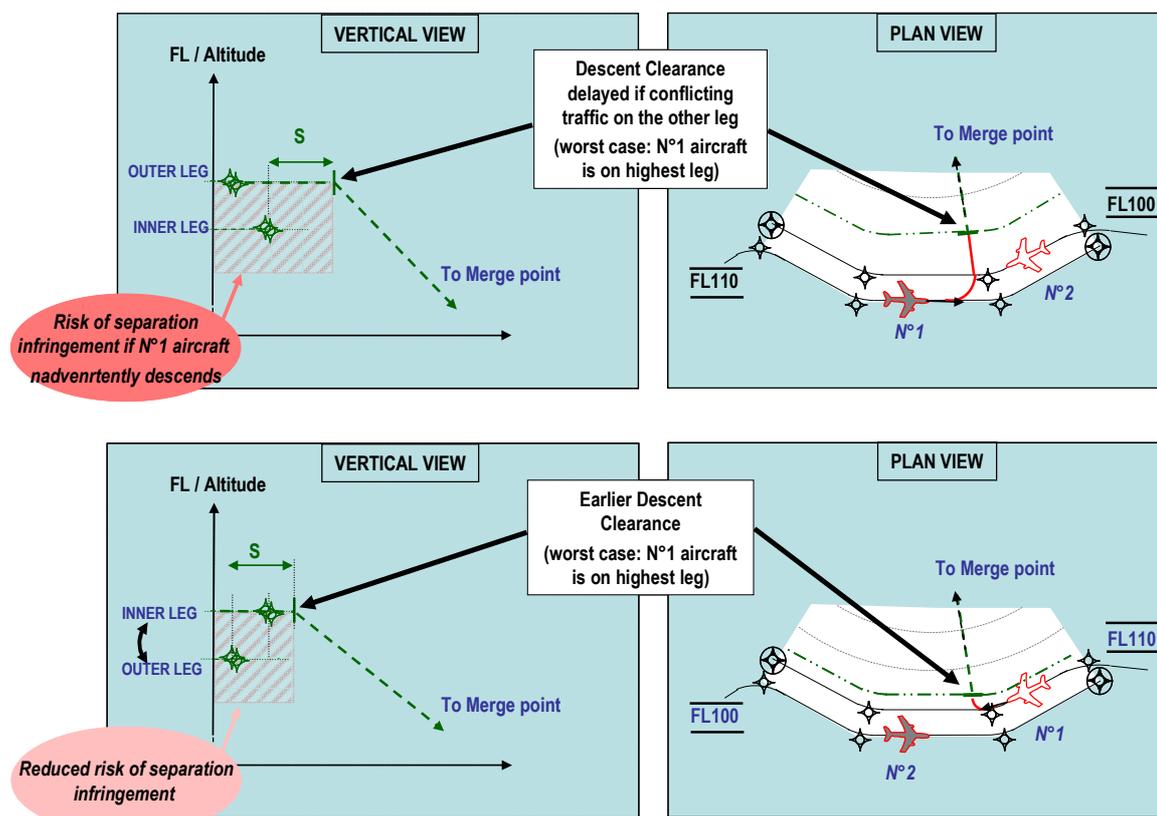
Regarding vertical separation between the sequencing legs, due consideration shall be given to the following aspects:

- As a general rule, differences in levels/altitudes used along the sequencing legs shall not be too large; this is due to the need to keep aircraft at compatible speeds for sequence building/maintenance, and in view of their descent for reaching the same altitude at the merge point while ensuring longitudinal separation;
- Parallel sequencing legs shall on the other hand be vertically separated as stated in §5.4 – e.g. each assigned with a different published level/altitude (i.e. at least 1000ft apart), using appropriate vertical restrictions. Consequently, again, in that case a trade-off has to be found between the two requirements.

Although it may not seem natural, a Point Merge system shall generally be designed with the inner sequencing leg at the highest FL/altitude. The main reason for this is that there would be a reduced risk of separation infringement in case an aircraft unexpectedly descends just after being instructed to turn direct-to the merge point.

An additional reason for this design choice is that aircraft – in particular those from the highest leg – may then be cleared for descent earlier (see Figure 8-8). Depending on the lateral/vertical separation between the sequencing legs and/or on the traffic context, this clearance may even be issued immediately after their turn towards the merge point whatever the leg they come from; the same controller might then successively issue the direct-to instruction and the descent clearance.

As a direct consequence, all other things being equal, there would then be a less stringent constraint on the minimum distance between the inner sequencing leg and the merge point (to ensure that all aircraft can descend towards the required altitude at the merge point according to their performances).



**Figure 8-8. Parallel sequencing legs: altitude design options**

### 8.2.9 Number of sequencing legs

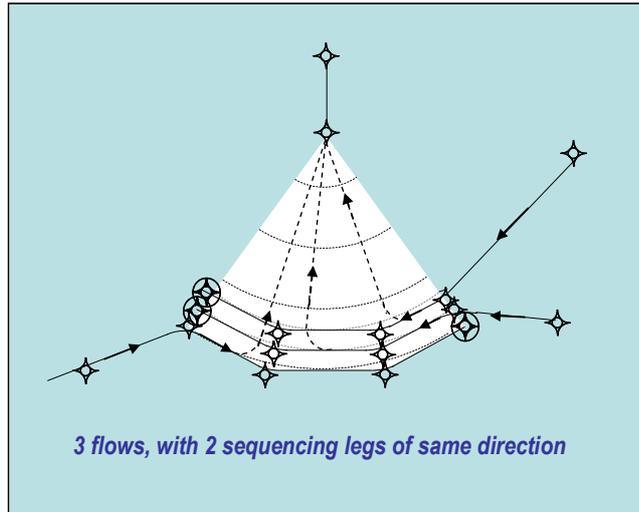
Depending on the number of inbound flows, it may be necessary to include more than two sequencing legs in the Point Merge design. Figure 8-9 below gives an example with three parallel legs in a single Point Merge system (§9.1.2.2 provides another example with four parallel legs, in approach airspace).

However with three or more parallel sequencing legs, the decision time to instruct the ‘direct-to’ turn towards the merge point may be significantly reduced if the leading aircraft is on the inner leg and the trailing aircraft on the outer leg.

In addition, such configurations would require a large number of levels to be used in total, a larger distance between the legs and the merge point to allow for descent, and possibly a smaller distance between the sequencing legs to ensure the equidistance requirement is adhered to.

With more than two levels used by the sequencing legs in a single Point Merge system, the availability of spare levels may also become an issue.

Finally, note that in order to deal with configurations involving more than two or three inbound flows, another solution may be to combine Point Merge systems (see §8.3).



**Figure 8-9. Example: three sequencing legs**

## 8.2.10 Symmetry and angles

### 8.2.10.1 Symmetry in a Point Merge system

It is recommended, as a general principle, to ensure symmetry in the design of a Point Merge route structure, be it for single or combined Point Merge systems, in order to:

- keep the operating method as simple and intuitive to apply as possible;
- ensure better predictability of trajectories flown.

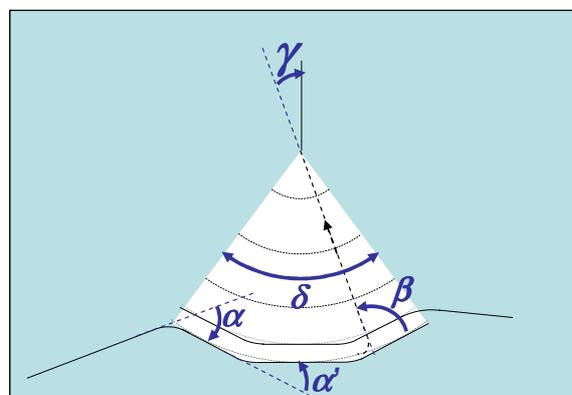
This symmetry principle applies in particular to distances (equidistance property, including the case of combined Point Merge systems, see §8.3.1) and angles (as detailed below).

### 8.2.10.2 Angles in a Point Merge system

The following angles can be defined in a Point Merge system (Figure 8-10):

- The track angle change at the first waypoint on the sequencing leg ( $\alpha$ ), and, in case of segmented legs, subsequent track angle changes at successive waypoints on a sequencing leg ( $\alpha'$ ,  $\alpha''$ ...);
- The track angle change corresponding to the direct-to instruction towards the merge point ( $\beta$ );
- The angle formed by the envelope of possible routes to the merge point ( $\delta$ );
- The track angle change at the merge point ( $\gamma$ ) – towards the exit of the Point Merge system.

Waypoints defining the sequencing legs (with the possible exception of the last point on each leg) and the merge point shall be fly-by waypoints (see Ref[24] and §5.4). Consequently,  $\alpha$  ( $\alpha'$ ,  $\alpha''$ ,...) and  $\gamma$  correspond to fly-by transitions.



**Figure 8-10. Angles in the design**

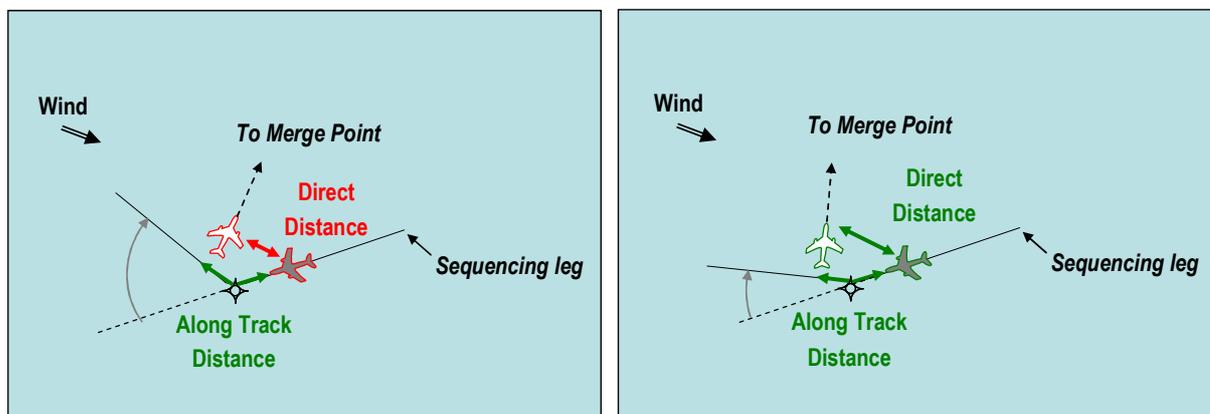
### 8.2.10.3 General guidelines inherited from P-RNAV

As a general rule for the design of a P-RNAV procedure,  $\alpha$  ( $\alpha'$ ,  $\alpha''$ ...) and  $\gamma$  shall be smaller than 120 degrees, and as these angles correspond to fly-by transitions, they should even as far as possible be smaller than 90 degrees<sup>69</sup>. As already stated in §8.2.3, track angle changes at waypoints, along with the length of segments and maximum anticipated wind are key factors in the procedure design (see Ref [24]). Furthermore, large track angle changes at waypoints may increase the sensitivity to heterogeneous aircraft turn performances.

### 8.2.10.4 Track angle changes along the sequencing legs

The value of  $\alpha$  ( $\alpha'$ ,  $\alpha''$ ...) will otherwise mainly be subject to design choices taking account of local constraints. However:

- With respect to the above symmetry principle, it is desirable to use similar values of  $\alpha$  ( $\alpha'$ ,  $\alpha''$ ...) along a particular sequencing leg, and for different sequencing legs in a single or combined Point Merge system, so as to avoid variability in along track distance (which may result in e.g. uncertainty in sequence order<sup>70</sup>).
- In addition, a large track angle change between segments of a sequencing leg i.e. a large value of  $\alpha$  ( $\alpha'$ ,  $\alpha''$ ...), may result in an increased risk of loss of separation between two successive aircraft on the same leg due to a larger sensitivity to variability in aircraft turn performances. Nevertheless this is not a Point Merge specific issue, as it applies for any RNAV procedure, with two aircraft on the same route with turning points.
- Finally, a large value of  $\alpha$  ( $\alpha'$ ,  $\alpha''$ ...) may result in a higher risk of loss of separation with the following aircraft on the same sequencing leg, when the lead aircraft is turning towards the merge point, as shown in (Figure 8-11), especially in certain wind conditions. Again, although it can be linked to a particular phase in Point Merge operations, this is not a specific Point Merge issue, as it can occur with any RNAV procedure involving two aircraft initially on the same route and the lead aircraft being vectored by ATC. In the figure below, with a large track angle change at the waypoint between two segments of a sequencing leg, when turning to the merge point, the closure rate with an aircraft flying along the preceding segment of the same leg may increase and become positive. Although the direct distance was larger than the required separation before that turn, the risk of loss of separation increases – and this may be aggravated by the wind conditions.



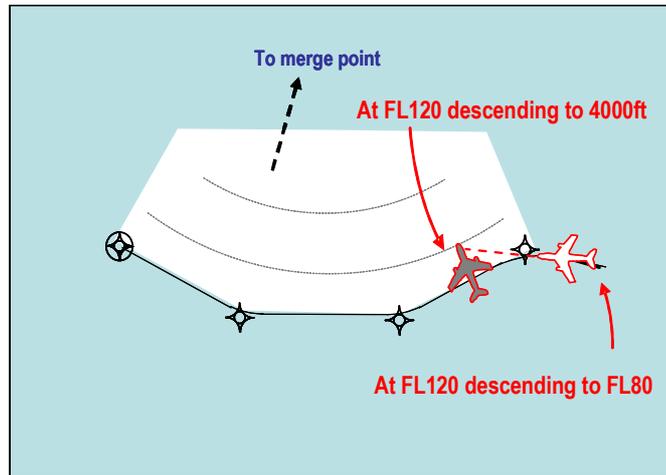
**Figure 8-11. Large track angle change at sequencing leg waypoint**

**Note:** A potential safety issue was mentioned by controllers participating to generic prototyping sessions on Point Merge operability assessment (Ref [22], session X-G, §15.3). This issue, concerning the design of the route that joins the sequencing leg, may need to be confirmed by a more specific safety study. As illustrated in Figure 8-12 below, loss of separation could occur if an aircraft does not turn along the defined route while another is already on course to the merge point. Such non-nominal behaviour, resulting in lateral deviation from the procedure, might be due to e.g. non-equipped aircraft that would not follow a heading instruction,

<sup>69</sup> Ref[10], §6.3.1: “Track angle changes must not exceed 120° in fly-by transitions. The fixed radius transition can be used for turns greater than 120° and should also be used for all turns in excess of 90°, wherever possible.”

<sup>70</sup> Especially if distance markers displayed along the P-RNAV route on the CWP are used as an aid by ATC to determine the sequence order.

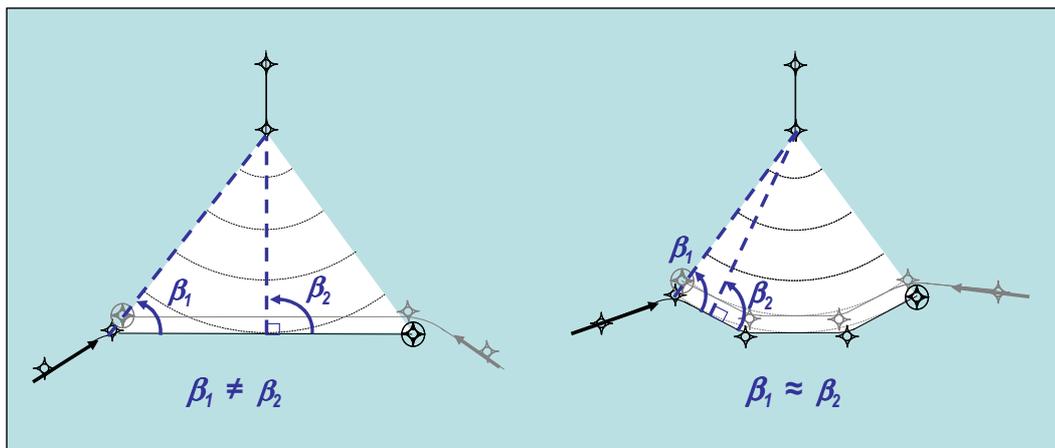
inadvertent change in navigation mode, or improper coding of the procedure. Note that this issue would concern a Point Merge design in which aircraft fly level off along the leg, or in which the legs are dissociated – with no levelling-off constraint then. Consequently, the track angle change at the first waypoint of the sequencing leg ( $\alpha$ ) may need to be carefully designed. To allow anticipation and clear detection of wrong behaviour by ATC, this angle could be either high (e.g. more than  $45^\circ$ ) which might cause difficulty due to the turn radius, or small enough (e.g. less than  $15^\circ$ ) to avoid too much divergence between route segments.



**Figure 8-12. Large track angle change at sequencing leg waypoint**

8.2.10.5 *Track angle change when turning to the merge point*

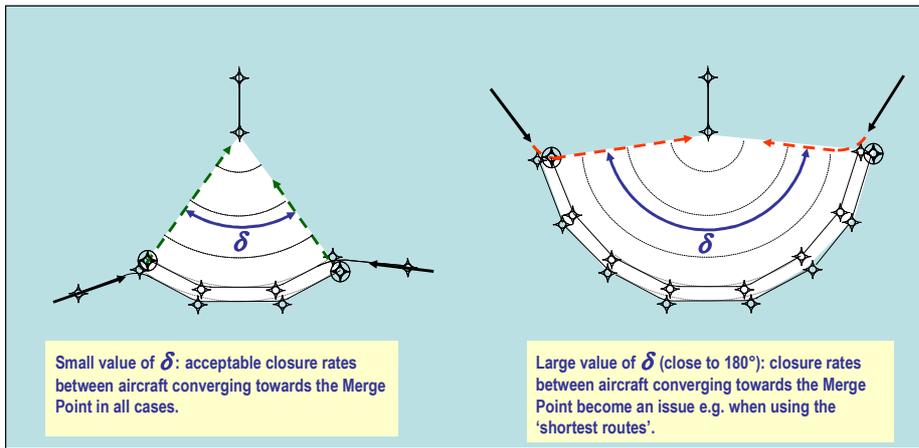
The value of  $\beta$  (track angle change when turning direct to the merge point), and its variability, might have some impact on the spacing variation when leaving the sequencing leg, depending on airborne systems performance regarding the way the ‘direct-to’ turn is implemented. This variability will actually depend on the shape and length of the sequencing legs: for segmented sequencing legs involving short segments far enough from the merge point,  $\beta$  will generally be more or less uniformly close to 90 degrees – with a limited impact then. However for long and straight sequencing legs (and/or closer to the merge point), the value of  $\beta$  may be subject to larger variations – i.e. smaller at the beginning and end of the leg and larger at the middle, inducing turn variability – potentially with an impact on inter-aircraft spacing.



**Figure 8-13. Variability in track angle change (direct to)**

### 8.2.10.6 Convergence angles towards the merge point

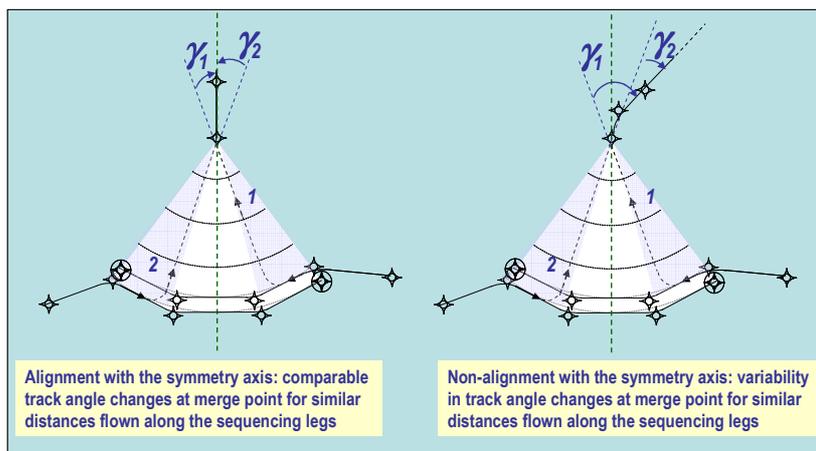
The maximum value of  $\delta$  is linked to the distance between the sequencing legs and the merge point, and the length of the sequencing legs. Large values of  $\delta$  should be avoided in order to limit the closure rate of aircraft being instructed the 'direct-to' the merge point early from different legs. In the worst case (with  $\delta=180^\circ$ ), this may result in head-on convergence to the merge point, with a high closure rate, hence less time to react in case of a separation issue and/or possible STCA nuisance alerts (Figure 8-14)<sup>71</sup>. In that case, the track angle change itself may be large as well, also inducing a larger sensitivity to heterogeneous aircraft turn performances and an increased sensitivity to wind effect.



**Figure 8-14. Convergence angle to the merge point**

### 8.2.10.7 Track angle changes after the merge point

The value of  $\gamma$  for any given aircraft is linked to the (fixed) direction of the final segment of the Point Merge system i.e. after the merge point, and to the (variable) track angle when on course to the merge point. Assuming the distances flown along the leg(s) by two successive flights in the sequence are roughly equivalent, as shown below, there will be similar values of  $\gamma$  as well if the final segment is aligned with the symmetry axis of the Point Merge system (or if the two aircraft were on the same leg). On the other hand, variability in the value of  $\gamma$  may be caused by the direction of the final segment not being aligned on the symmetry axis of the Point Merge system, for two aircraft from different legs. In turn, this variability could induce spacing variations at the merge point due to heterogeneous turn angles.



**Figure 8-15. Variability in track angle changes (after the merge point)**

<sup>71</sup> During the early prototyping of Point Merge (see Ref [21], session V), it was envisaged at some point to use different altitudes when sending aircraft to the merge point, so as to solve such issue with vertical separation. However this solution was subsequently discarded as the issue only occurred in case of strong convergence and such nose to nose convergence with high closure rates can be avoided with correct design.

In order to avoid such spacing variations, it is therefore recommended that the route segment from the merge point be aligned, as far as possible, with the symmetry axis of the Point Merge system (which is, again, consistent with the symmetry principle highlighted above). This is illustrated in Figure 8-15 above, in the case of parallel sequencing legs.

### 8.3 Combination of Point Merge systems

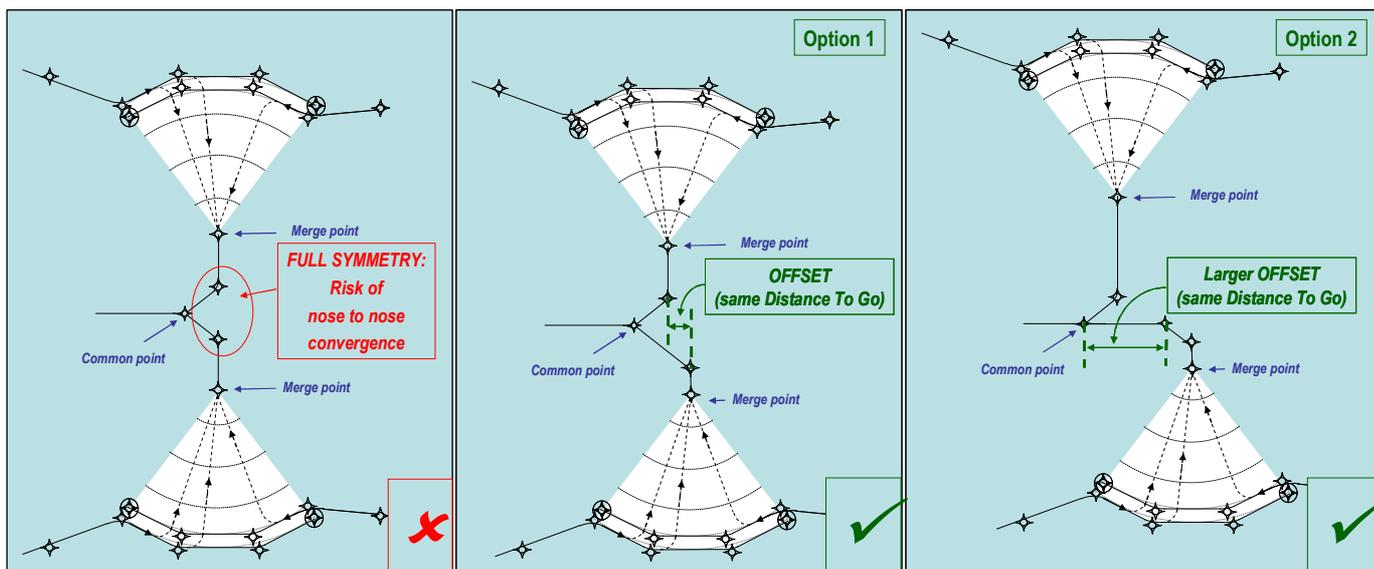
This section describes the main options for the combination of Point Merge systems into a route structure, i.e. ‘parallel’ or ‘serial’ combinations.

#### 8.3.1 Parallel combination of Point Merge systems

Considering the integration of a number of arrival flows through multiple entry points, instead of increasing the number of sequencing legs in a single Point Merge system as depicted in §8.2.9, it may be envisaged to combine multiple Point Merge systems. In that case, each system would include one merge point, and all would have a common exit point. The resulting route structure corresponds to a ‘parallel’ combination of Point Merge systems.

After aircraft leave the sequencing legs, the primary means for separation assurance shall be longitudinal spacing. In the case when two successive aircraft are located in different Point Merge systems, a projected longitudinal inter-aircraft spacing shall be considered. Therefore, in such route designs, it is recommended that **the equidistance property** be ensured not only within each Point Merge system (between the legs and the merge point), but also between any sequencing leg and the common point within the combined route structure. This will ease the visual assessment of spacing between two successive aircraft in all cases, having the **same distance to go** to the common exit point.

Figure 8-16 below illustrates typical options for such combinations, involving two Point Merge systems in a symmetrical configuration, supporting the integration of four arrival flows into a single flow.



**Figure 8-16. Multiple Point Merge systems – options for ‘parallel’ combination**

In addition, in analogy with ILS interception, and with regards to the route structure between the merge points and the common exit point:

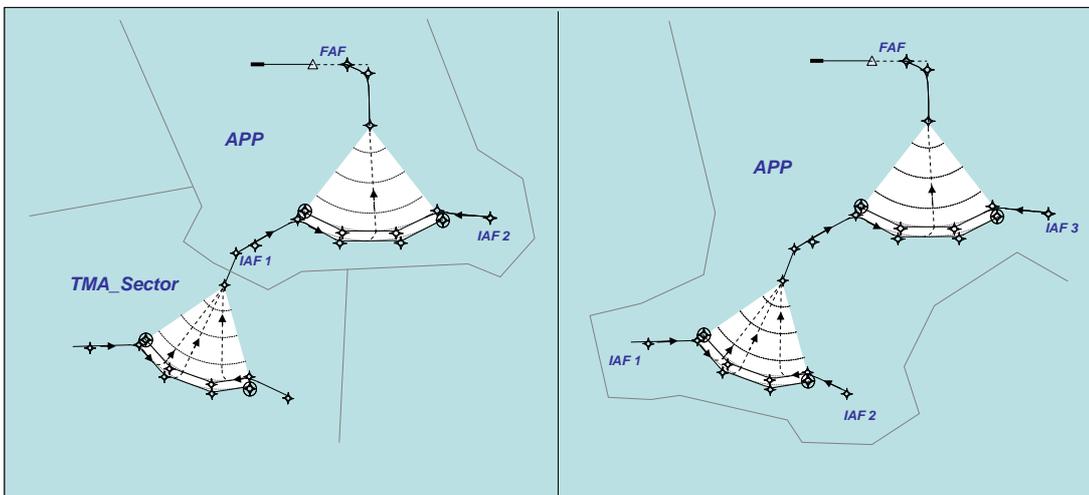
- A **vertical separation** shall be ensured between the two flows converging towards the common point. This will enable dealing with the (non nominal) case when two aircraft from different Point Merge systems would arrive close to this common point without having achieved the required spacing, which could result in a ‘nose-to-nose’ situation, i.e. a strong lateral convergence with high closure rate, towards the common point<sup>72</sup>.

<sup>72</sup> This would be similar to the nose-to-nose convergence case within one single PMS with too large an angle as depicted in §8.2.10.6.

- A **lateral offset** shall be introduced between the two Point Merge systems, without prejudice to the ‘same distance to go’ symmetry requirement mentioned above, in order to avoid ‘nose to nose’ convergence even before turning towards the common point (see initial safety assessment and Refs [26], [27]). This offset may be achieved by adjusting in the route design the length of segments between the merge points and the common point (Figure 8-16, option 1). However, even in that configuration, aircraft would still be converging towards a common point defining a fly-by turn. To further mitigate the risk of nose-to-nose convergence, the design could also incorporate an offset in the intersection points with the common axis (Figure 8-16, option 2).

### 8.3.2 Serial combination of Point Merge systems

Due to the progressive nature of the integration of arrival flows, it may be envisaged to combine successive Point Merge systems, corresponding to a ‘serial’ configuration. This could reflect specific constraints in the Approach, or a use of the Point Merge technique with a split between E-TMA/TMA and Approach, as illustrated in Figure 8-17 below. Note however that such configurations have not been tested yet.



**Figure 8-17. Example: options for successive Point Merge systems**

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## 9. Annex: Point Merge applications

This section discusses the application of Point Merge for metering or separation purposes, in Approach airspace or in E-TMA (i.e. respectively after or before the IAF), and with different airspace characteristics. It also discusses the main applicability issues in Approach.

### 9.1 Application to approach

The application of Point Merge to the Approach, for the integration of arrivals into a single sequence to a runway, is concerned with separation – the main constraint to be applied at the exit of the Point Merge system being the separation on final.

#### 9.1.1 Applicability: approach environment

The applicability of the new procedure to a specific terminal airspace has to be determined on a case-by-case basis through a local study, taking account of all relevant airspace, traffic and operational constraints.

Local constraints may impose specific design choices; conversely, some environments may offer flexibility in the design of a Point Merge system. In any case, it is expected that the scalability and wide range of variants in the geometry of a Point Merge route structure will enable considering in such studies different potential local solutions in a number of varied environments, based on those principles detailed in §5 above. In particular, it is anticipated that the design of the supporting P-RNAV route structure / Point Merge system(s) will be determined by Terminal Airspace characteristics, such as:

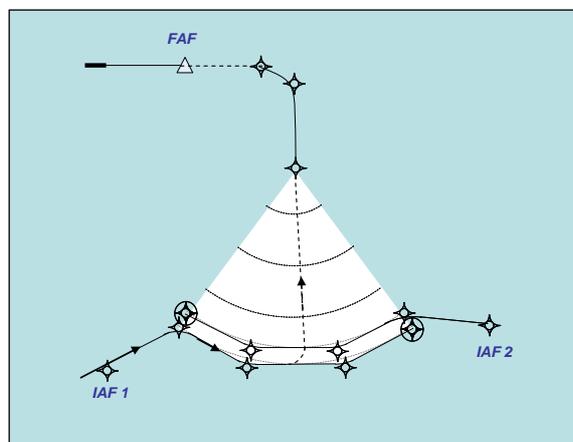
- The number of inbound flows (e.g. number of IAFs);
- The number of runways, and runway usage (mixed vs. specialised mode, allocation strategy);
- The frequency of runway configuration changes;
- The available airspace, taking into account environmental constraints and other airspace usage constraints (TSAs, etc.);
- The complexity of arrival/departure flows and related segregation constraints, which may be function of e.g. the existence of secondary airports.

#### 9.1.2 Typical examples

Various cases are considered, depending on the number of entry points, of runways, runway mode, size of TMA.

##### 9.1.2.1 Two entry points, single Point Merge system with parallel sequencing legs

This example considers arrival flows from two entry points (or two IAFs) towards a single runway, and two parallel sequencing legs with a levelling-off constraint. In this case the application of the Point Merge procedure would typically involve a route structure similar to Figure 9-1 below:



**Figure 9-1. Application to Approach: two entry points, one runway, parallel legs**

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Typical dimensions: sequencing legs defined at FL100-FL120, merge point at 6000ft (located about 25nm from touchdown), with a distance between the sequencing legs and the merge point in the range of 20nm.

In addition to the general conditions and entry conditions identified in §7.1 above, the following specific entry condition applies: inbound aircraft are stable at appropriate (similar) speeds at the Point Merge system's entry, according to published restrictions and/or ATC instruction. This is intended to help ensuring longitudinal separation between successive aircraft on the same sequencing leg;

As far as ground actors are concerned, Table 9-1 below provides an example task allocation, with reference to the steps defined in §7.1, Table 7-2. In that case, two Approach positions (APP, FIN) are each manned by an executive controller (respectively APP\_EXC and FIN\_EXC)<sup>73</sup>; in addition, an Approach planning controller (APP\_PLC) is handling coordination.

Step #	ATC task	Actor
1	Check /confirm sequence order	APP_PLC and APP_EXC
2	Check entry conditions (altitude, speed, separation) and issue instruction as required.	APP_EXC
3	Monitor the spacing behind the preceding aircraft in the sequence.	
4	Issue Left/Right direct-to merge point.	
→ Transfer to FIN_EXC		
5	When clear of other traffic, and when/if appropriate according to altitude/level window at merge point (or at the Point Merge system exit), and to the ILS interception altitude: issue descent clearance to ILS interception altitude.	FIN_EXC
6	Use speed control to deliver the aircraft at an optimised spacing and at an appropriate speed.	
7	After the aircraft exits the Point Merge system, issue ILS interception clearance.	
→ Transfer to TWR runway controller		

**Table 9-1. Task allocation example with parallel sequencing legs**

It is assumed that at first contact, APP\_EXC clears the aircraft for the Point Merge procedure.

The inter-aircraft spacing criterion for the direct-to instruction depends on the runway separation, as well as necessary margins to ensure subsequent sequence maintenance/optimisation through speed control, and WTC separation criteria (step 6). It is based on a distance value that can be reflected through specific distance markings on the controllers' HMI (such as the "range rings" centred on the merge point as per §10 below).

As the sequencing legs are parallel, the descent instruction following the direct-to shall only be issued once clear of traffic on the other leg. It is even further recommended that the descent clearance be systematically dissociated from the 'direct-to' instruction<sup>74</sup>, to mitigate risks related to routine and/or reduced vigilance. With two approach positions, a simple way of both ensuring the dissociation and reinforcing the clear of traffic condition may be to have the descent clearance given by FIN\_EXC, after the aircraft is transferred by APP\_EXC (as illustrated in Table 9-1 above). In that case, a 'transfer of control/descent limit' may even be materialised on the CWP as a reminder (e.g. dotted line, parallel to the inner sequencing leg).

When possible, ATC will clear the aircraft for descent towards the ILS interception altitude. The latter will be the target altitude for the computation of the vertical profile by the airborne system.

As stated above (§5.1.3 and §7.1), aircraft will exit the Point Merge system while flying along a common path: the procedure will thus provide homogeneous exit conditions and in approach, allow a standard ILS intercept. The ILS clearance will be instructed by FIN\_EXC, and the aircraft will intercept the localizer,

<sup>73</sup> See §13.5.

<sup>74</sup> (Ref [25]): if the 'direct-to' and the descent clearance are given in the same radio contact, there may be a risk that the aircraft starts descending without being laterally separated from aircraft on the other leg; there is also a risk that the aircraft starts descending whilst its course is still on the sequencing leg. Both cases could result in a loss of separation with traffic on the parallel sequencing leg.

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then the glide slope, after which FIN\_EXC will transfer the flight to the Tower.

In order to join the axis and fly the ILS procedure, the Point Merge procedure shall include either an RNAV leg or a fixed heading with an appropriate angle towards ILS axis. In case the merge point is offset from the axis, no heading phase is required provided the intercept angle achieved with the RNAV procedure is within the ILS alignment tolerance window around the axis<sup>75</sup>. The merge point may also be located along the runway axis, subject to local constraints. In the case when the merge point is located close to the FACP<sup>76</sup>, co-ordination with the navigation data providers is recommended so as to ensure consistent waypoint use (see Ref [24]).

Ref [19] and [21] provide more details on the initial validation of such applications of the Point Merge procedure.

Notes:

1. The description above is only provided as an example. Local considerations may lead to different choices in terms of positions/manning, task allocation and transfer. For instance, there may be places and/or periods of time with medium/low traffic load where APP and FIN positions could be grouped, resulting in one executive controller in approach – instead of two as depicted above.
2. The description above assumes a precision instrument approach with an ILS – however Point Merge is compatible with other approach procedure such as e.g. RNAV approach.
3. With vectoring, and in case of two executive controllers, transfer between APC\_EXC and FIN\_EXC would generally occur at varied distances from the runway axis, depending on e.g. the traffic load. With Point Merge, a transfer area can be precisely defined (and, as stated above, if deemed necessary, be materialised on the controller’s HMI with a specific graphical marking).

*9.1.2.2 Four entry points, one runway, single Point Merge system*

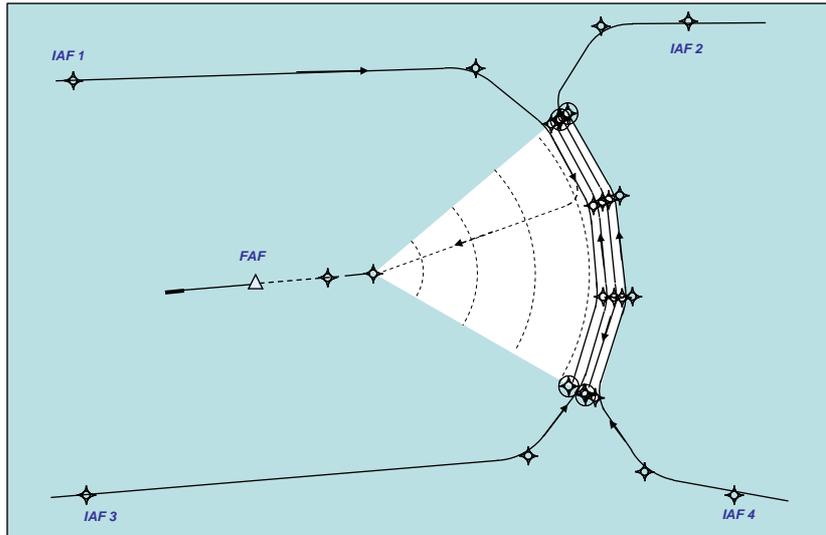
Figure 9-2 and Figure 9-3 show two examples with four IAFs (or four entry points) feeding one runway. The first example relies on four parallel sequencing legs, and the second one on two dissociated sets of parallel sequencing legs.

In the first case, the use of the procedure would be more intuitive and less sensitive to wind conditions than the second one. However, although this design is simpler in principle, as stated in §8.2.9 above, this case would require at least four levels for the legs (instead of two for the second case – provided the two sets of sequencing legs are appropriately separated laterally), and a larger distance between the legs and the merge point for aircraft to descend. In addition, to easily determine the appropriate moment to issue the ‘direct-to’, the first design with four parallel legs would also require a smaller separation between the legs (e.g. 1nm) to keep the distance between the inner and outer legs smaller than the required spacing. In turn, with legs separated e.g. by only 1000ft and 1nm, more ATC monitoring would be required to ensure that aircraft enter, and fly along the legs at the correct FL/altitude. Finally, with four parallel sequencing legs, availability of spare levels (as recommended in §6.4) may be an issue.

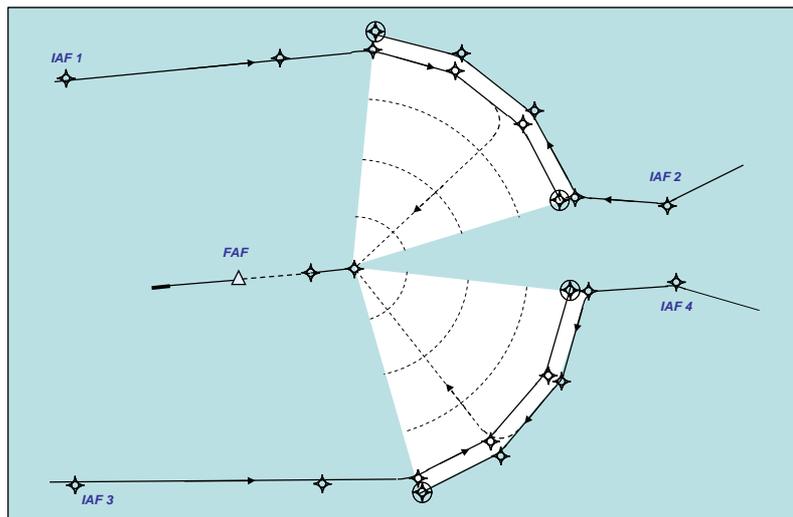
It should also be remarked that those two examples would involve a larger distance flown for westerly flows (from IAF1 and IAF3) due to a longer downwind leg. Multiple Point Merge systems as depicted in 8.3.1 above would on the contrary result in a more balanced distribution of distance flown between the traffic flows.

<sup>75</sup> e.g. +/- 3 degrees - otherwise an RNAV curve might result in a false capture of a ‘side-lobe’ of the localiser and consequently paralleling of the final approach course; after the merge point, the RNAV route would then have to end prior to the ILS localiser interception and a (magnetic) route would have to be defined allowing the LOC interception with an appropriate angle.

<sup>76</sup> Localizer based approaches always include at least an approach entry point called a Final Approach Course Fix (FACP), a Final Approach Fix (FAF), a runway threshold, and a missed approach procedure. Localizer signal reception is assured on the leg from FACP to FAF.



**Figure 9-2. Example with four entry points, one runway, four parallel sequencing legs**



**Figure 9-3. Example with four entry points, one runway, two dissociated sets of legs**

All these options were assessed in a generic environment (Ref [22], sessions I, II, III, IV, VII , - §4, 5, 6, 7 10):

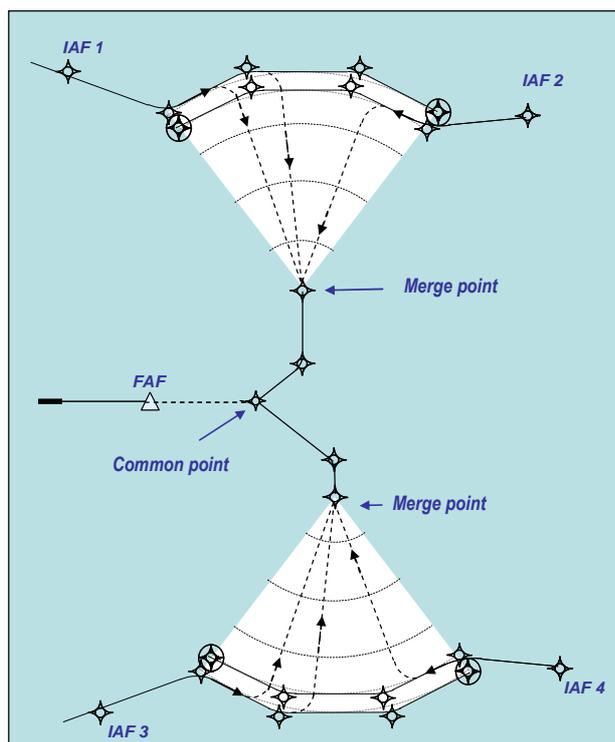
- The configuration with four parallel sequencing legs (Figure 9-2) was deemed operationally feasible – most of the drawbacks mentioned here above were not considered as major issues;
- On the other hand the configuration with two dissociated sets of sequencing legs and a common merge point (Figure 9-3) raised two issues: potential head-on situations (with safety implications) and large turns at the merge point (resulting in loss of spacing accuracy). Consequently, it is strongly advised to use two merge points (one for each set of legs) instead of a single one, leading to a common point and resulting in configurations as depicted in §9.1.2.3 below.

#### *9.1.2.3 Four entry points, one runway and combined Point Merge systems*

In order to alleviate the issues raised in case of two sets of sequencing legs and a single/common merge point in §9.1.2.2 above, this example considers arrival flows from four IAFs towards a single runway, and the combination of two Point Merge systems with two merge points and a common point. Each Point Merge system consists of two close parallel sequencing legs with a levelling-off constraint (Figure 9-4). This case

would typically involve a route structure as depicted below (see also Figure 8-16 in §8.3, and §10.1). General conditions and entry conditions are similar to those described in §9.1.2.1 above.

In this example, two Point Merge systems are combined, jointly supporting the integration of the four arrival flows. There are two merge points, after which the procedure ends with a common point located on the runway axis. A lateral offset between the two Point Merge systems enables avoiding ‘nose-to-nose’ converging configurations – in case of unexpected situations. Nevertheless, a sufficient symmetry in the system is ensured (as recommended in §8.3.1) as the distances to go from the two merge points to the runway are the same, and distances to go from the two outer (rep. inner) sequencing legs to the runway are also the same. This is aimed at easing the visual detection of spacing between two successive flights that would not be located in the same Point Merge system. Finally, similarly to 9.1.2.1 above, CDAs are possible from the sequencing leg altitude/level.



**Figure 9-4. Application to Approach: one runway, combined Point Merge systems, parallel legs**

Ref [22] (sessions I, II, III) provides more details on the initial validation of such applications of the Point Merge procedure. During these validation sessions, the use of two dependent systems was found totally feasible, with similar perceived benefits as with a single system. Integrating aircraft from two systems was easy but slightly less accurate than with a single system. For that reason, the controllers tended to group aircraft by system.

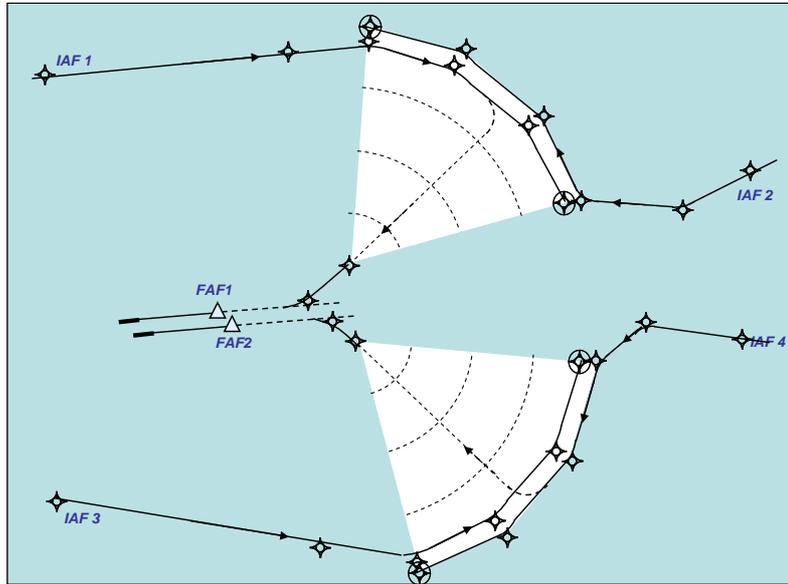
The same considerations on actors and task allocation would apply as in §9.1.2.1 above for two IAFs – in particular ground actors could be the same i.e. one APP\_EXC and one FIN\_EXC. However:

- Although there are two merge points in such a configuration, an appropriate spacing between two successive flights is expected to be achieved as soon as they leave the sequencing legs, even when they are located in different Point Merge systems. APP\_EXC thus needs to take into account aircraft in the two Point Merge systems to decide when to issue the direct-to turn instruction.
- Complementing the vertical separation requirement as per §8.3.1: in order to minimise the risk of separation infringement before ILS interception from different merge points, some flexibility may be introduced in the vertical separation. This can be achieved in two different ways:
  - either all aircraft are cleared to the same altitude (e.g. 4000ft), and upon passing the merge point, further descent to 3000ft can be used if needed;

- or two different interception altitudes are used (e.g. 3000ft from a merge point and 4000ft from the other one).

9.1.2.4 *Four entry points, two runways and two Point Merge systems*

Figure 9-5 shows an example with four entry points (or four IAFs) feeding two runways, relying on two Point Merge systems (also see §10.2).

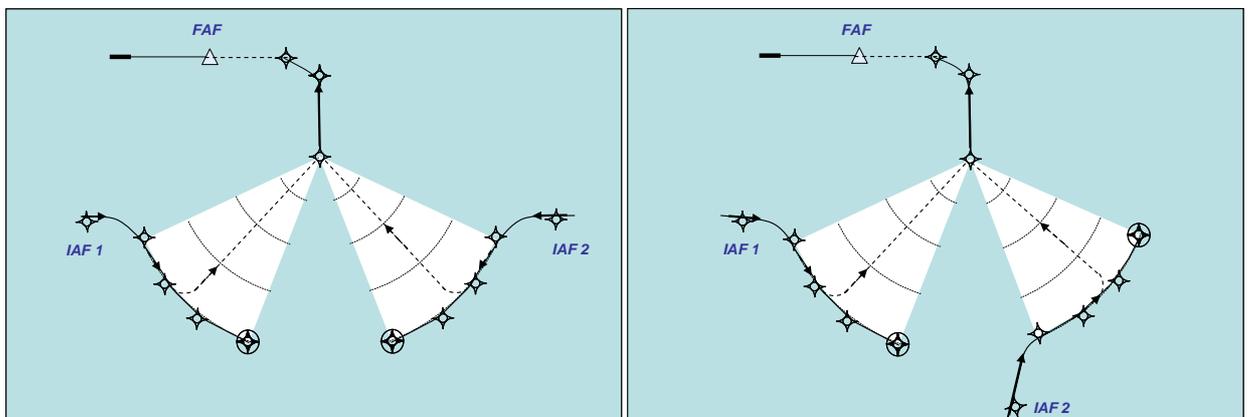


**Figure 9-5. Example with four entry points, two runways, two Point Merge systems**

This design could be used in the context of geographic runway allocation, or in case of medium/low traffic, in the context of a runway allocation strategy aiming at minimising taxi time (see §9.1.2.9 below).

9.1.2.5 *Two entry points, one runway, dissociated sequencing legs*

In that configuration, sequencing legs are not parallel anymore, but dissociated (with sufficient lateral separation) as illustrated below. Subject to local constraints, they may either require more airspace, or have to be shorter (so as to reduce sensitivity to wind conditions – see §8.2), possibly resulting in more stringent metering requirements at the entry of the Point Merge system. Figure 9-6 below illustrates different configurations with dissociated sequencing legs (same or opposite direction).



**Figure 9-6. Application to Approach: dissociated legs for advanced continuous descent**

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Entry conditions are similar to those described in §9.1.2.1 above, except that aircraft may already be in descent when entering the Point Merge system.

Actors and task allocation would be the same as in §9.1.2.1, with the exception that the levelling off constraint along the sequencing legs is released, and the descent clearance (e.g. to the ILS interception altitude) may be issued prior to the ‘direct-to’ turn instruction towards the merge point – even prior to the sequencing leg’s entry (and step 1). Consequently CDAs may become possible at least from the IAFs, even though there is an uncertainty on the ‘distance to go’, equal to the length of the sequencing legs. Appropriate altitude restrictions should be defined in the procedure.

Local constraints, such as strategic de-confliction from other flows, may also impose the use of vertical restrictions at the end points of the legs. Finally, subject to the length of the sequencing legs, or in case of partly dissociated legs with a parallel part (see §5.2), it may be considered appropriate to level off along the last part (or segment) of the leg. As this part of the procedure would only be used by a minority of aircraft, i.e. in case of non-nominal situations, this would nevertheless enable an efficient descent along the legs for the other ones.

Initial validation has shown that, subject to appropriate traffic presentation in the longitudinal dimension (metering) and vertical dimension (similar altitudes), such a procedure with e.g. 15nm or 21nm long sequencing legs is operationally viable and feasible (Ref [22], sessions IX, X, XI, §12 to 17):

- From the cockpit standpoint, including various aircraft weight and wind conditions;
- From the ground standpoint in nominal conditions – although it was reported to be less easy than with aircraft levelling-off along the sequencing legs.

However, this type of Point Merge design would still have to be assessed from a controller’s perspective under a range of different non-nominal conditions – e.g. under strong wind.

Note: In such configurations, instead of clearing each inbound flight to the ILS interception altitude at first contact, for safety reasons it might be desirable to clear the descent towards an intermediate level at the end of the sequencing leg<sup>77</sup>, and later/closer to the runway, further clearing to the ILS interception altitude (without normally impacting the vertical profile). This would allow coping with potential issues such as:

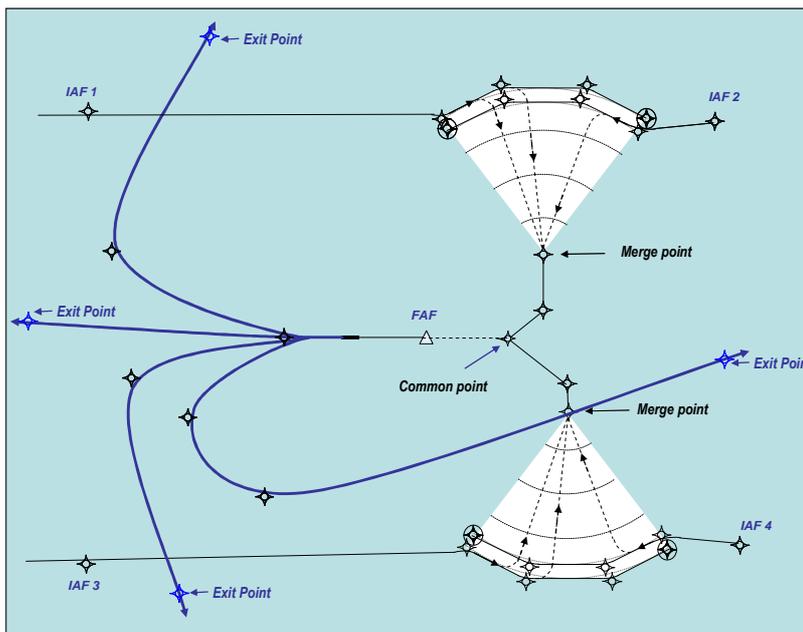
- Early issuance of a descent to an altitude along with QNH information,
- Or radio failure after an early descent clearance is issued.

#### 9.1.2.6 Departures in a Point Merge environment

The design of departure routes in a Point Merge environment for arrivals shall follow the same principles as per Ref [9], in particular regarding the strategic separation of routes. Due consideration shall be taken of aircraft climbing performances in the departure phase. For instance, depending on the distance between the downwind arrival legs and the runway axis, departure flows may pass above or below these legs. This could in turn impact on the possibility to combine continuous climb departures on the one hand, and CDAs from prior to the entry of sequencing legs on the other hand. Figure 9-7 below provides an example of RNAV SIDs in a configuration with 4 IAFs, 1 runway. As is already the case today, subject to local practices/conditions, some flexibility in the management of departures may be introduced by either letting aircraft follow the entire SID, or shortening their path by instructing a direct-to the exit point.

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<sup>77</sup> Ref[22], sessions IX and X.



**Figure 9-7. Example: departure routes**

More details on the inclusion of departures in the generic assessment of Point Merge procedures can be found in Ref [22], sessions II and III (§5 and §6).

#### 9.1.2.7 The case of a small TMA

In a small TMA, the dimensions of a Point Merge system will obviously be reduced, and an efficient upstream traffic metering may be required. More precise direct-to instructions will be required so as to achieve an efficient initial longitudinal spacing towards the merge point, as there will be less room for speed control. This will also result in less flexibility regarding changes in the sequence order due to the risk in sequencing leg run-off. In addition, when defining roles and procedures, and especially the sectorisation and task allocation, due consideration should be taken, in such an environment, of the (smaller) number of aircraft simultaneously on the frequency, with an impact on the balance of workload between the ground actors.

In effect, initial validation has shown that, subject to appropriate metering in upstream sectors according to the capacity of a small TMA, such a procedure would be acceptable from the ground standpoint in nominal conditions, with e.g. 15nm long parallel sequencing legs, designed at FL60/FL80 and located at 10nm from the merge point (Ref [22], §10). It was nevertheless mentioned that there was less flexibility compared to a larger Point Merge system due to the reduced margin along the legs and to the merge points. Regarding the roles and procedures, the collapsing of two approach positions into a single one (one executive controller) was therefore tested and also found feasible, under nominal conditions.

#### 9.1.2.8 Change in the runway in use

Different Point Merge route structures need to be defined in Approach airspace for each runway configuration. The principle, as in current environments, is to limit the impact on upstream sectors<sup>78</sup>. In particular, to the extent possible, one should seek to keep the same IAFs. No other issue than already experienced today is anticipated: the change of runway in use is planned and coordinated; specific traffic metering measures may be needed.

<sup>78</sup> See Ref[9], §5.4.2 Terminal Routes: “R2.1: To the extent possible, terminal routes should consistently be connected with the En-Route ATS network irrespective of runway in use [...] R2.2: To the extent possible, irrespective of runway in use, terminal routes should be compatible with routes in adjacent terminal airspaces [...] R2.3: To the extent possible, change in the runway in use should create minimum operational complexity to the terminal routes structure [...] this guideline suggests that the terminal route structure for one runway configuration should seek to mirror that of the inverse runway configuration so as to minimise operational complexity.”

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#### 9.1.2.9 Multiple landing runways

In multiple runways configurations, various runway allocation strategies can be used:

- Geographic allocation (according to the arrival flow). This strategy leads to less complex situations in the air, but may result in longer taxi times, depending on the airport terminals taxiways and runways layout. With Point Merge operations, this might translate into a Point Merge system dedicated to each runway, with some flexibility for limited runway allocation changes, which would have to be coordinated in advance.
- Minimum taxi time (according to destination gate/stand, and associated taxi time). This strategy is generally used under low to medium traffic conditions, as it would otherwise result in complex interactions and route crossings in Approach airspace. Various options could be considered in a Point Merge environment (shorter, dissociated legs dedicated to different runways, late changes with increased separation margins, etc...). However, it is not expected that Point Merge would create more opportunities to use this type of allocation strategy than radar vectors, especially under high traffic loads.

More details on the case of two landing runways with geographic allocation in the generic assessment of Point Merge procedures can be found in Ref [22], sessions V and VI (§8 and §9).

Note: in case of dependent runways, with a Point Merge system dedicated to each runway, parallel approaches may use different ILS interception altitudes if necessary to ensure vertical separation (e.g. 3000ft or 4000ft, similarly to the case when two Point Merge systems are combined to feed a single runway).

#### 9.1.2.10 Mixed mode operations

In that case, the principle does not differ from current practices. Departures may be accommodated by increasing the separation on final approach and then use available slots between successive arrivals.

Subject to local practices, there could also be tactical decisions on “packing” and “gapping” arrivals coordinated between the Tower and the Approach, so as to balance runway usage for arrivals and departures. Such tactical co-ordinations could in turn lead to tactical changes in the required separation on final for arrivals; further validation would be required to assess their operability in the context of Point Merge. In particular, due to less flexibility with Point Merge once the direct-to instruction to the merge point is issued (i.e. only speed adjustments in the normal procedure/nominal conditions), a larger look-ahead time may have to be delivered by TWR for packing or gapping the arrival sequence. The use of an AMAN may help provide an adequate co-ordination support in this type of operations.

### 9.1.3 Summary of results

A series of sixteen small-scale human-in-the-loop simulations conducted between October 2005 and end 2008 allowed progressively defining and refining Point Merge (in terms of design, procedure and working method), assessing its feasibility, benefits and limitations (Ref [20], [21], [22], [33]). Varied generic TMA environments were considered under high traffic, nominal and non nominal conditions. Although the primary focus was on the controller’s side, flight deck aspects were also addressed.

The outcomes were very positive. Point Merge was found comfortable, safe and accurate, even under high traffic load, although less flexible than today’s working method (vectoring).

From a controller perspective, compared to today, the method provided a reduction of workload and communications, more predictability and anticipation, a clear and better tasks repartition between controllers through a change of roles. Under strong wind conditions, the method was found totally feasible and not more difficult than today with similar wind.

These results are confirmed by analysis of measurements from real time simulations (Refs [21], [22]): decrease in number of instructions at both arrival positions (29% for approach, 57% for final) and of frequency occupancy (~10% for approach and 44% for final); more balanced task repartition with ~60/40 split of instructions between controllers (~70/30 in the baseline), and a medium frequency occupancy, notably for final (45% versus 80% in the baseline). The change of roles is reflected by the geographical distribution of instructions: early integration by approach controller with direct-to (as opposed to late integration on the axis by the final controller in to the baseline).

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From a pilot perspective, in addition to the reduction of communications (typically each aircraft received slightly less than 6 instructions, versus more than 10 instructions in baseline), aircraft remained on lateral FMS guidance as heading instructions were no longer used, hence enhanced situation awareness and predictability.

From an operation perspective, even under high traffic load, the inter-aircraft spacing on final was as accurate as today (runway throughput maintained), while descent profiles were improved (continuous descent from legs level/altitude e.g. FL100). Notably, the median value of average altitude profiles was found to be significantly higher (typically 9500ft, approximately doubling from 4800ft in the baseline, for sequencing legs at FL100/110)<sup>79</sup>.

The flow of traffic was more orderly with a contained and predefined dispersion of trajectories. Distance and time flown in TMA were similar. In addition, fast time modeling have been conducted (Ref [23], [34]), showing a potential average fuel saving of 100kg per aircraft in TMA (continuous descent approach when leaving the legs).

According to the controllers, all these elements should also contribute to improving safety.

It was also shown that Point Merge can be adapted to typical terminal area configurations with benefits in terms of staffing (standardisation of working methods), predictability (extensive use of lateral FMS guidance) and environment (advanced continuous descent) even under high traffic load.

Issues raised were possible decrease of vigilance and, in the longer term, potential loss of vectoring skills; typical mitigation is recurrent training.

Overall, these studies demonstrated the applicability of Point Merge in TMA, with clear benefits in terms of standardisation, safety, predictability and efficiency/environment. Most generic aspects were covered in varied environments including nominal and non-nominal situations. The application of Point Merge in TMA is therefore considered ready for deployment. Further investigations could consider evolutions towards more advanced CDAs (with systematic descent along the legs), and dynamic airspace structures i.e. transitions between Point Merge systems to cope with e.g. high versus low traffic demand.

## 9.2 Application to E-TMA

### 9.2.1 Comparison with TMA

The application of Point Merge to extended TMA has the same objective as for TMA/Approach; i.e. path stretching/shortening<sup>80</sup> while remaining in FMS navigation. This may be applied not only for separation purposes, but also for metering towards TMA entry points.

We tried to address applicability to E-TMA initially by identifying what elements could make it *a priori* feasible or not feasible. This was done by analysing respectively similarities and differences with TMA operations.

#### What could make it feasible?

Similarities between sequencing in E-TMA today and sequencing in TMA with Point Merge:

- Sequencing on a pre-defined point (not on an axis - as in TMA today)
- Sequencing in two distinct steps: path stretching/shortening followed by speed control in descent (not mixed - as in TMA today)

Note: For Point Merge design, a simplistic approach would be to define the sequencing legs based on the vectoring/path stretching patterns.

<sup>79</sup> This value was obtained from measured real time sessions, by defining an average vertical profile of recorded trajectories between FL110 and 3000ft, over a 65nm distance, and computing its median. Although not having a strict mathematical significance, the difference in values indicates a strong trend for improvement.

<sup>80</sup> As for TMA, it is assumed that due to traffic demand/presentation, speed control is not enough to achieve the sequence with required spacing at exit point.

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### What could make it not feasible?

Differences between sequencing in TMA with 'point merge' and in E-TMA with 'point merge':

Entry conditions

- Multiple entry points: need for multiple legs or multiple levels?
- Less homogenous traffic presentation (traffic not metered, different levels at sector entry): need for multiple levels on same leg?

Sequence building

- Traffic with heterogeneous speed/altitude profiles and performances: need to achieve speed and altitude compatibility before entering the sequencing legs, hence legs to be designed before the TOD rather than at sector entry? (aircraft at high cruise FL to perform an initial descent?);
- Less airspace available (than in TMA): do we need more than today in the considered E-TMA sectors? need to look at vectoring patterns – this may impose new geometry of legs?
- Larger dimensions of the system (higher altitude/level, higher speed, longer distance to the merge point): different timescales of actions?
- Aircraft at high speed (hence less absorption capability than in TMA): do we need more than today in the considered E-TMA sectors?
- Metering constraints in addition to separation: adherence to varied (static or dynamic) inter-aircraft spacing requirements?
- Large track angle changes (90° on Direct-To): same as today? Or need to get used to it?

Sequence maintaining

- Vectoring in descent: if due to late flow integration, see below - any other reason?
- Late flow integration (while in descent): if flows balanced, need for dissociated legs to avoid level-off? - if not, a leg for the minority flow may need to be sequenced depending on main flow (in descent and not impacted).

### 9.2.2 Case study

DSNA and EUROCONTROL launched a joint study to investigate the potential applicability, benefits and limitations of Point Merge for ACC arrival sectors (Ref [35]). The motivation for DSNA was to investigate solutions which would be applicable in French airspace, and for EUROCONTROL at a pan-European level.

The study started in January 2009 and had two phases:

- A series of six small scale real-time simulations (“prototyping sessions”) conducted at the Experimental Centre with a core team of controllers to develop and refine the application (three participants, 19 days of simulation in total, from February to November 2009).
- A two week session conducted at Paris ACC to expose the application to a large panel of controllers (36 participants in total, four per day, during 9 days in March/April 2010).

During its first phase, the study followed an iterative approach, in which the objectives of each prototyping session depended on results of the preceding one. The first sessions mainly investigated feasibility and operability (e.g. variants of design, working methods, role). Once sufficient maturity was reached, assessment of benefits was conducted (comparison with a baseline situation). The environment was gradually enriched so as to simulate more comprehensive and realistic operations (two metering points, overflights, wind, high traffic load, arrival manager and current constraints).

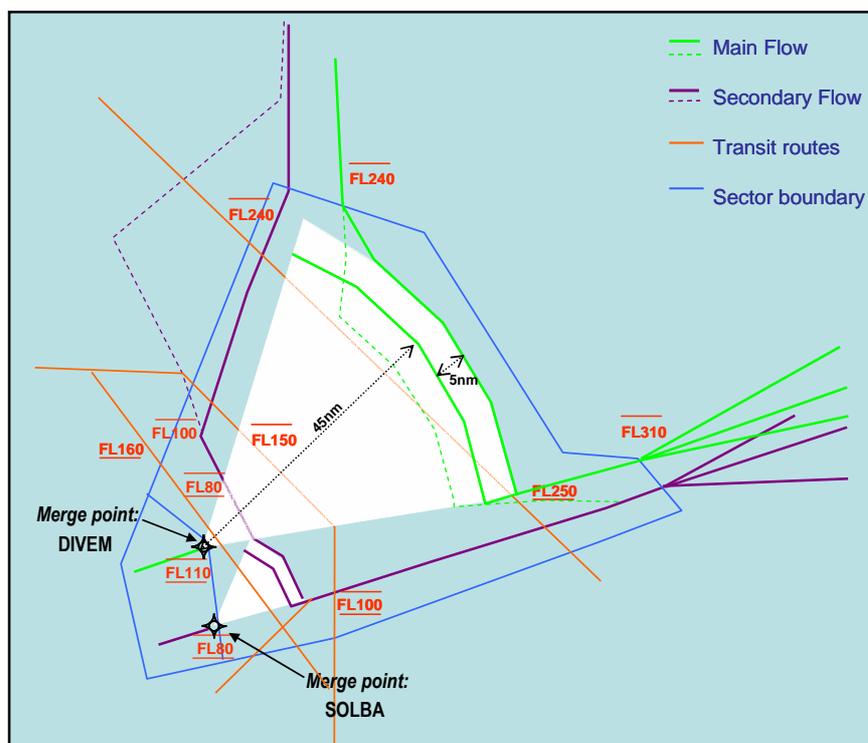
The simulated area was based on “TE” and “AP” sectors that feed the Paris TMA from the North East and that are adjacent to airspace managed by the Maastricht Upper Area Control Centre. The assumption was that if Point Merge is applicable to this complex and constrained environment, it could be considered for other ACC arrival sectors in Europe.

The area involved two arrivals flows (main and secondary, with distinct delivery points) and overflights. The operational objective was to build the two sequences by achieving 8nm spacing at each delivery point, while respecting additional arrival manager slots (for aircraft which will join the main sequence in downstream sectors).

There were two distinct Point Merge systems, one for each flow, separated by design (Figure 9-8). The main system was made of two sequencing legs<sup>81</sup>, of ~45nm length and 45/50nm<sup>82</sup> from the merge point (DIVEM). Due to traffic presentation, multiple levels are available on the legs: FL240(default)/FL230 for the outer leg, FL250(default)/FL260/FL270 for the inner leg. Intermediate points on each leg could also be used to deconflict traffic. Typical speed on the legs (with high traffic) is 260kt IAS. The secondary system, not overlapping with the main one, is smaller and closer to its respective merge point (SOLBA); it is made of two legs of ~15nm length and 12/15nm from the merge point, at FL100 (inner) and FL80 (outer). Feeding routes are located outside the main system to reduce interferences as much as possible.

The area was handled by two executive controllers (TE1 and TE2) assisted by a planning controller, with the following task allocation: TE1 build the main arrival sequence by issuing a direct to DIVEM when spacing behind a preceding aircraft has been achieved or when an arrival manager slot has been respected (for aircraft joining in downstream sectors). TE2 adjusts the sequence by issuing descent and speed instructions, and manages the secondary sequence (to SOLBA). For the main flow, continuous descents were possible when leaving the legs until the exit point.

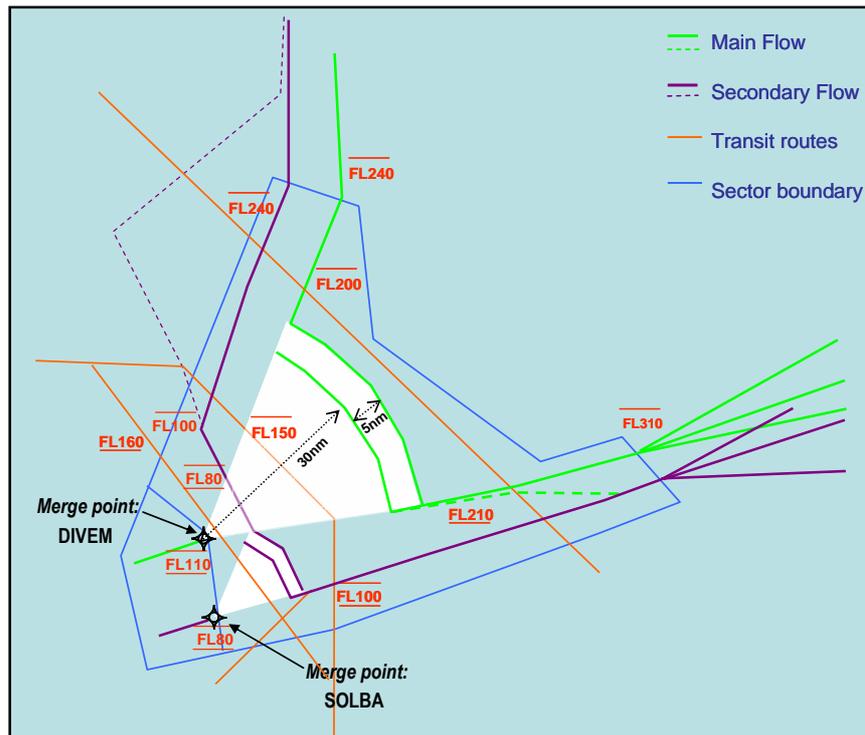
A second version of Point Merge (Figure 9-9) was tested with dimensions of the main system reduced by 30% to be considered when less airspace is available (eastern boundary moved to the West by ~15nm to reflect the existing environment when the military area ‘CBA16’ is active).



**Figure 9-8. E-TMA sector with two arrival flows**

<sup>81</sup> A third bidirectional leg for low altitude arrivals at FL210/FL220 (minority).

<sup>82</sup> A 5nm distance was set in view of depressurisation.



**Figure 9-9. E-TMA sector with two arrival flows (reduced)**

### 9.2.3 Summary of results

The outcomes from both phases were consistent and positive.

From the session conducted at the EEC, controllers reported that Point Merge is easy to use and facilitates the sequencing of arrival flows while respecting arrival manager slots; overflights are however considered to be penalised. They also reported that Point Merge increases controller availability with a better division of tasks, more anticipation, less workload and communication. This is confirmed by the analysis: 10% overall reduction of instructions, 40/60 split in instructions between controllers (20/80 in the baseline), peaks of frequency occupancy below 60% (80% in the baseline). In addition to receiving fewer instructions, aircraft remained most of the time under FMS lateral navigation (98% for main the arrival flow, versus 60% in the baseline).

Controllers considered that safety was improved, due, in particular, to reduced workload and therefore increased controller availability. However, they stressed the need to remain vigilant and mentioned a risk of loss of vectoring skills. Performance in terms of traffic delivery to the TMA and flight efficiency were similar to the baseline, as were distance and time flown and fuel consumption (variance in distance and time flown were slightly reduced). Flown trajectories were more orderly with a contained dispersion. With the increased availability, controllers reported a potential for safely increasing capacity.

From the session conducted at Paris ACC on the training simulator, the feedback from the controllers was very positive. The main benefits were: easiness and robustness of the procedure, a better and clearer division of tasks and roles, reduction of workload and of communication, enhanced safety and capacity; better delivery to approach and a better view of the arrival sequence. Limitations were: sensitivity to vertical aspects with the need to strictly respect levels on the legs (analogy with holding patterns) and the compatibility with existing receiving conditions (aircraft sometimes transferred late and at high altitude); sequencing of the secondary arrival flow was not always intuitive or optimised. Controllers reported the need to investigate abnormal situations (strong wind, etc).

From a service provider perspective, other benefits were identified: better airspace management (best use of available airspace, clear determination of airspace capacity); continuous initial descent (although level-offs along the legs); no need for any system modification or new technology.

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Overall, the study has shown that Point Merge is applicable to ACC arrival sectors. Point Merge has substantial potential to improve safety and increase capacity with current airspace constraints, without increasing distance flown. Careful consideration should be given to the vertical aspects, including entry conditions.

Further studies would be necessary to confirm the applicability of Point Merge on other sectors and with full scale arrival manager operations. DSN is envisaging further investigations with a view to preparing for possible implementation to support the sequencing of arrivals for Paris CDG (Northern runways).

In the light of the Point Merge investigations in the TMA, and now in the extended TMA, it is expected that Point Merge should support the improvement and standardisation of arrival operations, from top of descent down to final approach, in a pan-European perspective and with existing technology. It should be a sound basis on which further improvements could be developed, such as a better integration with the TMA and arrival manager (to support collaborative decision making and continuous descent from cruise to final under high traffic); the link with Functional Airspace Blocks and flexible use of airspace; and the move towards trajectory based operations including controlled time of arrival in the context of SESAR (Cf. §14 and §15).

## 10. Annex: Ground standpoint

The pictures below are actual screen captures from real-time prototyping sessions with air traffic controllers, in various 'generic' configurations including approach and E-TMA.

Note: coloured overlay areas have been added to the screen captures to identify the Point Merge systems.

### 10.1 Example 1: approach with four entry points, one runway

In this example, four entry points are feeding one runway using two Point Merge systems (North and South) – and two merge points before joining a common point. This type of configuration is discussed in §9.1.2.3 and §8.3.1. A lateral offset has been introduced between the two Point Merge systems; however the whole system still has the required built-in symmetry (i.e. the distance to go is the same from the northern legs or the southern legs) so that the controller can easily assess the spacing between two successive flights that would be located in different Point Merge systems, using the graphical markers on his/her display. In this configuration, traffic was managed by an approach executive controller and a final director, before hand-off to the Tower. Finally, it should be noted that the sequencing legs are parallel with a levelling-off constraint, but a continuous descent is already possible from the sequencing legs (i.e. ~FL100).

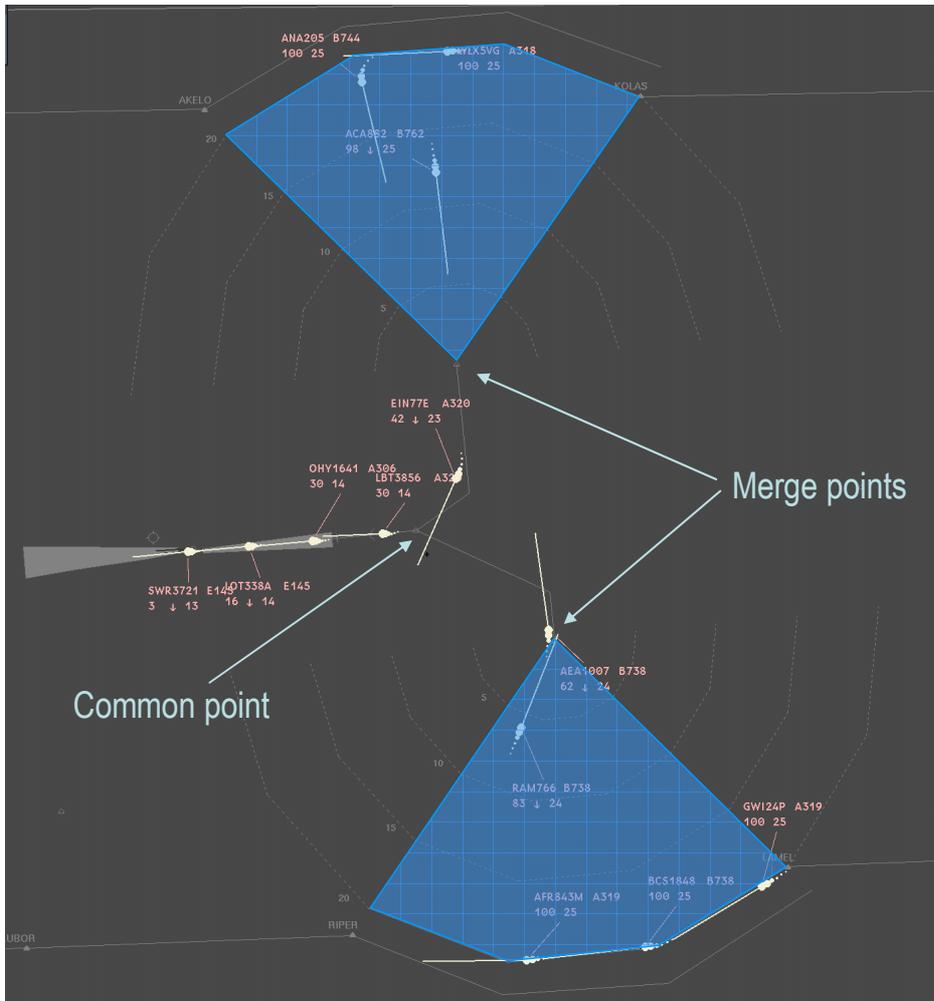


Figure 10-1. Controller display: four entry points, one runway



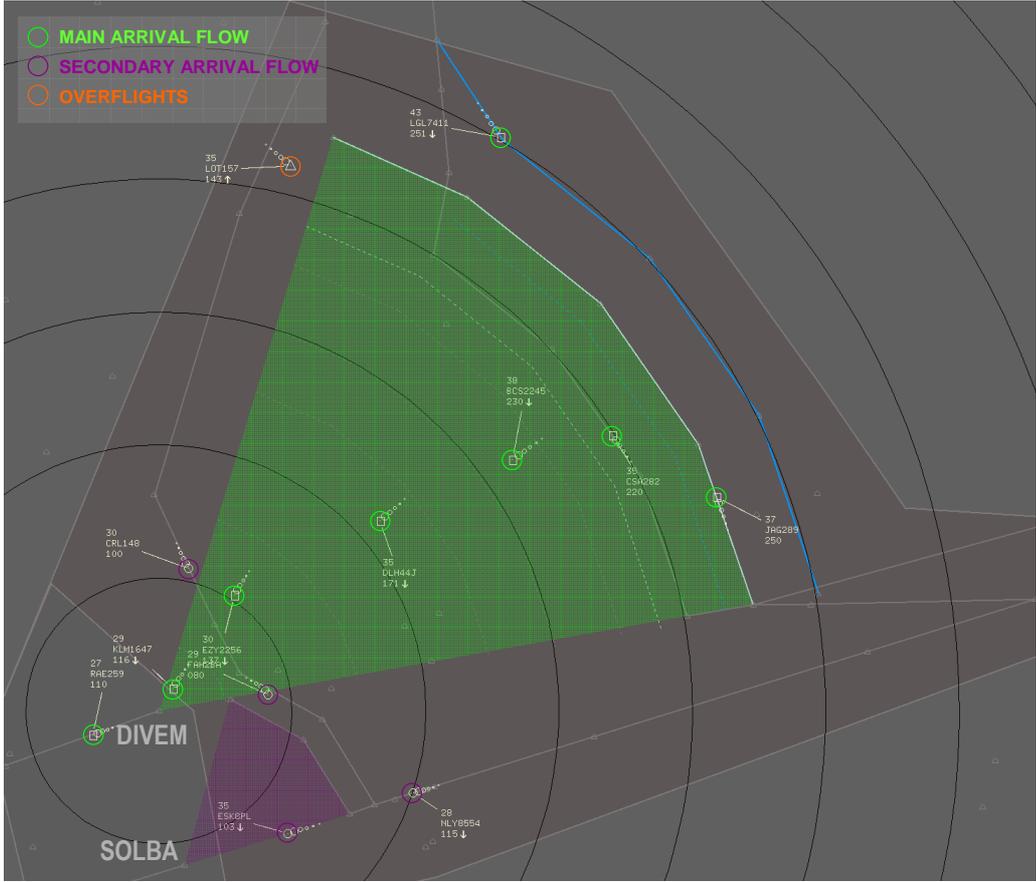


Figure 10-3. Controller display: E-TMA sector with two arrival flows



## 11. Annex: Cockpit standpoint

### 11.1 Example 1: sequencing legs with level-off

The following pictures were taken during a simulation of a Point Merge procedure on a B737 Full Flight Simulator. In this example, there is a levelling off constraint along the sequencing leg, as it is part of a Point Merge system with two parallel legs (see e.g. §9.1.2.1).

Figure 11-1 shows the Point Merge procedure as displayed on the ND before the aircraft enters the sequencing leg. The merge point is MERGO; the sequencing leg comprises points DW011 to DW015, and is at FL070 (note the FL070 constraint displayed on DW011).

*Note: in this simulation, DW015 is a fly-by waypoint, but according to §7.4.1 recommendations, and subject to local implementation choices, it could be defined as a fly-over point.*

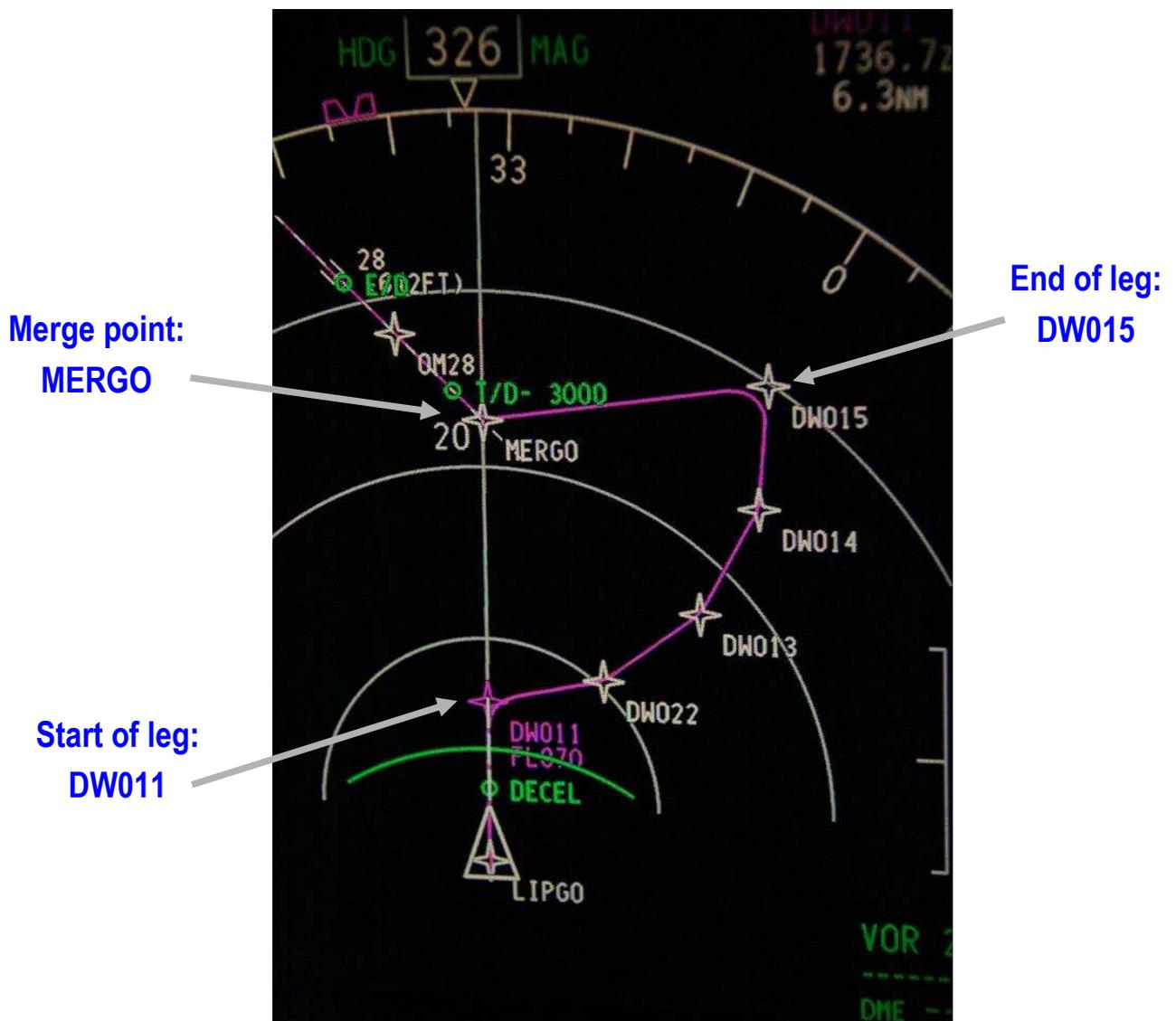


Figure 11-1. Cockpit view: before sequencing leg (level-off)

Figure 11-2 shows the ND and PFD as the aircraft enters the sequencing leg, having passed the first point (DW011), and is level at FL070.



**Figure 11-2. Cockpit view: entering the sequencing leg (level-off)**

Finally Figure 11-3 shows the ND display when the pilot inputs the 'direct-to MERGO', having been instructed to do so by ATC shortly after passing DW022 on the sequencing leg.



**Figure 11-3. Cockpit view: 'direct to'**

### 11.2 Example 2: sequencing leg without level-off

The following pictures were taken during a simulation of a Point Merge procedure on an A330/340 Full Flight Simulator at Technische Universität Berlin. In this example, the sequencing legs are dissociated and aircraft can be in descent at all times. There is a vertical restriction at the first point of the sequencing leg so as to ensure that even an aircraft turning immediately to the merge point will be able to descend – with a short distance to go then (see e.g. §9.1.2.5).

Figure 11-4 shows the Point Merge procedure as displayed on the ND and PFD before the aircraft enters the sequencing leg. The merge point is CADDY2; the sequencing leg, comprises points EC120 to EC122. A vertical restriction (FL120) and a speed restriction (250kt) have been defined on the first point of the sequencing leg. The aircraft is about to pass FL140 in descent.

*Note: in this simulation, EC122 is a fly-by waypoint, but according to §7.4.1 recommendations, it should normally be defined as a fly-over point.*



Figure 11-4. Cockpit view: before sequencing leg entry (no level-off)

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Figure 11-5 shows the ND and PFD as the aircraft flies along the sequencing leg at 220kts IAS, passing an intermediate point, and FL114 in descent.



Figure 11-5. Cockpit view: along the sequencing leg (no level-off)

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## 12. Annex: Additional guidelines

### 12.1 Minimising ACAS/TCAS nuisance RAs

As a general rule, any airspace (re)design process should consider the effect of TCAS. In particular, procedure designers should ensure that no ‘TCAS hotspots’ are created i.e. that the risk of TCAS nuisance Resolution Advisories (RAs) is minimised as far as possible<sup>83</sup>.

If there are very few airspace constraints, where possible, it is recommended to let traffic level off in places where the nearest traffic is 2000ft apart, in order to avoid nuisance RAs. However it is realised that in a busy airspace, this will generally not be possible.

An initial study was carried out at the EEC in 2008 (Ref [28]) to identify the situations where there is a risk of nuisance RAs with a Point Merge procedure used in Approach, and recommend solutions. The study focussed on parallel sequencing legs of opposite directions, with level off, a single level used on each leg, and 1000ft between the legs. This type of design may induce in particular descents with 1000ft level-off situations as well as vertical crossings situations along the legs and/or at their extremities.

It shall be borne in mind that the conclusions presented here are valid for airspace where airspeeds are nominally limited to 250kts. In airspace with larger speeds, the conclusions of the study would need to be reviewed and/or adapted.

The study concluded that there are three situations in which nuisance RAs might occur due to the particular characteristics of this design: levelling-off above another close parallel sequencing leg (§12.1.1), levelling off prior to leg entry point (§12.1.2), levelling-off below another close parallel sequencing leg (§12.1.3).

Resulting nuisance RAs can then be avoided by:

- Ensuring by design 7nm horizontally between traffic flows (this figure accounts for navigational errors), or
- Limiting the rate of descent of the upper aircraft to 1500 fpm<sup>84</sup> in the last 1000ft before levelling off.

Note: the study also recalled the need to make sure in any local implementation that the remainder of airspace and procedures are TCAS compatible - i.e. that there are no other situations which can cause nuisance RAs. These include in particular (see Ref[28] for more details): protection of the legs from non arrival traffic, transponder testing facilities, military formation flights, separation from VFR traffic, closely spaced parallel runways, visual clearances. It is expected that such an assessment will be carried out locally for each particular application of Point Merge (as should actually be the case for any Terminal Airspace Design activity).

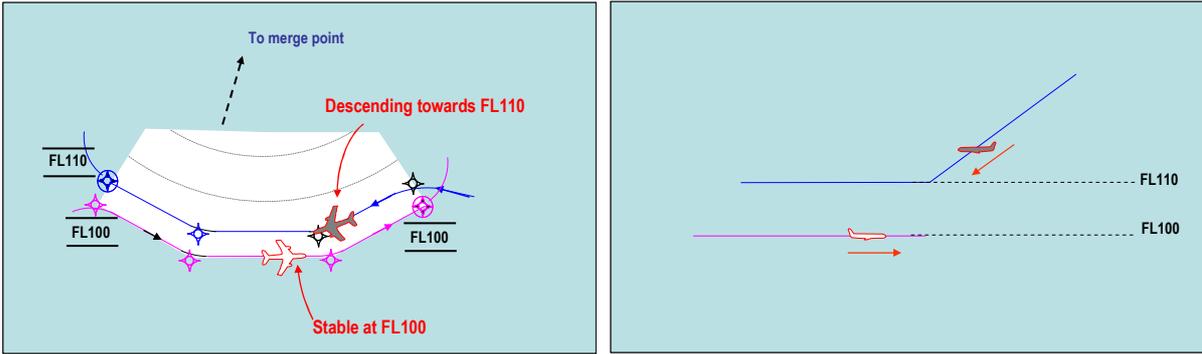
#### 12.1.1 Levelling-off above another close parallel sequencing leg

In Point Merge configurations involving close parallel sequencing legs of same or opposite directions – with e.g. levelling off along the last segments of the legs – nuisance RAs might be triggered if an aircraft flying along the upper leg descends to the required level. This is illustrated by Figure 12-1 below.

Note: in all figures of this section, FL values (100 and 110) are only provided for illustration purposes.

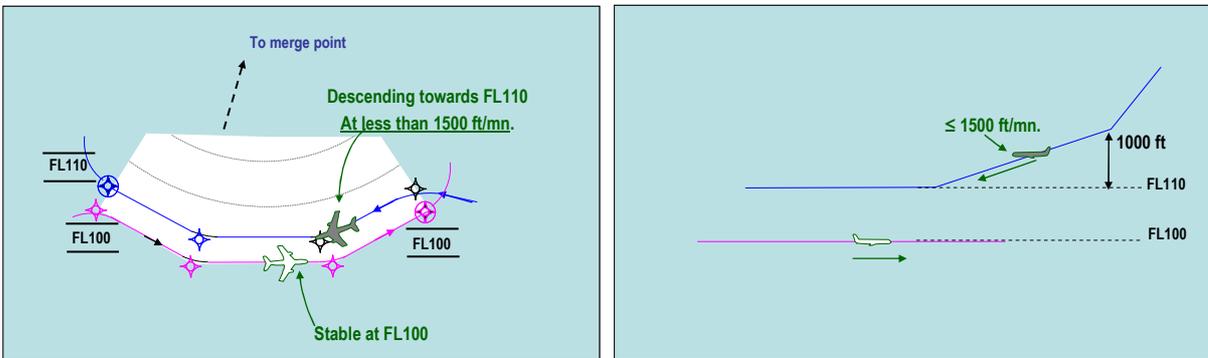
<sup>83</sup> Ref [9], Part C, §5.4.2 states that “[...] designers and planners should take various other factors into account in the determination of the vertical distance between the aircraft at the crossing point. These include: [...] Nuisance ACAS alerts: an appreciation of how ACAS Traffic and Resolution Advisories might be triggered by route geometry [...]”.

<sup>84</sup> ICAO guidance currently recommends (Annex 6, Aircraft Operations) to reduce the vertical rate to less than 1500fpm in the last 1000ft before level-off at the cleared altitude. In situations when both aircraft may be levelling off simultaneously, it is appropriate to use the stricter EUROCONTROL ACAS Programme recommendation that pilots climb or descend at a rate less than 1000fpm in the last 1000ft to level-off. Cf. Ref[29], Ref[30] and Ref[31] (available from the EUROCONTROL web site). The study of *ACAS issues with Point Merge* (Ref[28]), based on practical observations, concluded that the ICAO recommendation is sufficient for Point Merge.



**Figure 12-1. Nuisance RA – descending to upper leg level while on the leg**

In such a situation, nuisance RAs can be avoided by a vertical solution i.e. restricting the descent rate of the upper aircraft to 1500fpm in the last 1000ft before level-off (Figure 12-2), as already recommended by ICAO.

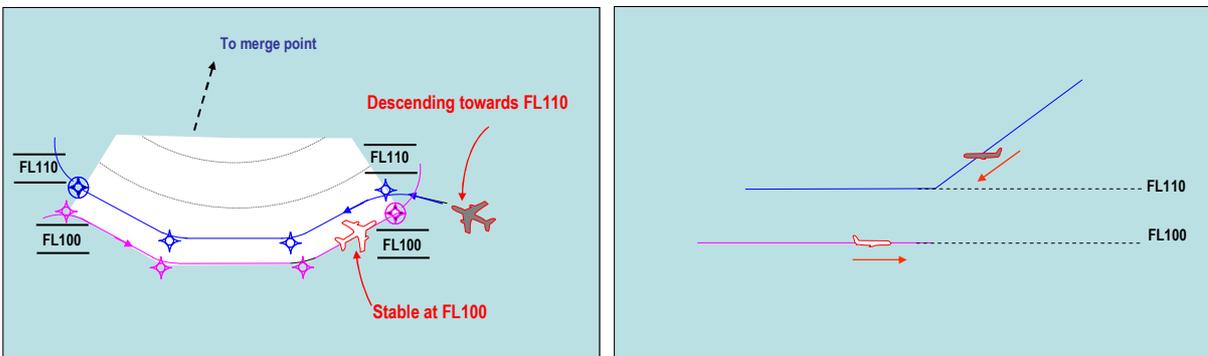


**Figure 12-2. Nuisance RA – descending to upper leg level while on the leg: vertical solution**

Note: it is left to ANSPs to decide, in the frame of a local implementation, whether a specific note in the AIP or supporting AIC should reinforce this ICAO recommendation – or if published vertical restrictions should further be included in the procedure so as to influence the vertical profiles accordingly.

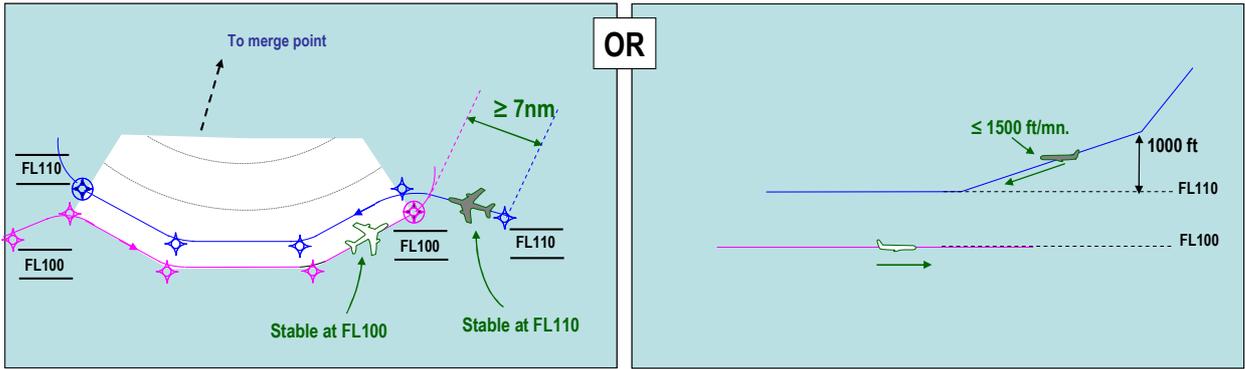
### 12.1.2 Levelling off prior to leg entry point

Similarly, nuisance RAs might be triggered when an aircraft is descending to the required level before joining the upper leg, and another is flying level close to the end of the lower leg i.e. 1000ft below, as illustrated in Figure 12-3 below.



**Figure 12-3. Nuisance RA – descending towards the upper leg entry**

Such nuisance RAs can be avoided either by constraining the descent profile of the upper aircraft (as above), or by ensuring that there will be enough lateral distance from another aircraft on the lower leg when the upper aircraft reaches its level (the recommendation from Ref [28] is 7nm, accounting for navigational errors).

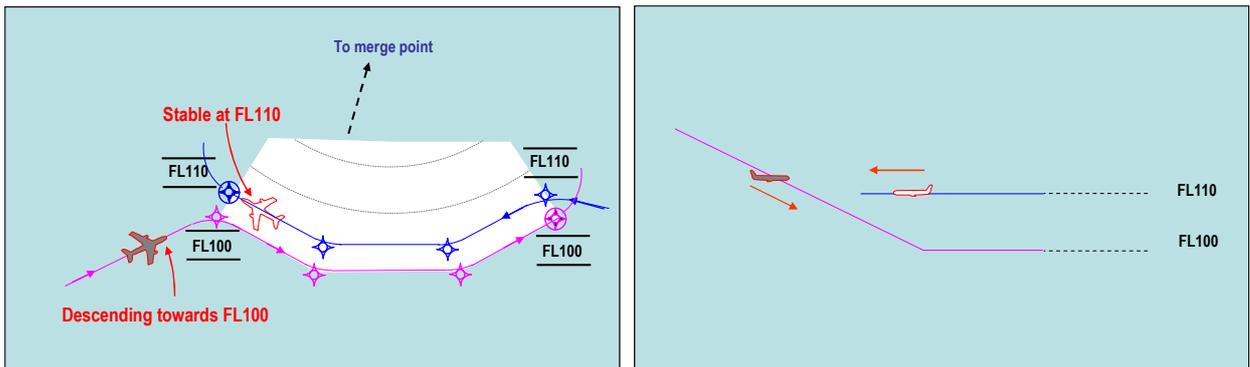


**Figure 12-4. Nuisance RA – descending towards the upper leg entry: horizontal or vertical solution**

In terms of Point Merge procedure design, the ‘horizontal solution’ above may translate into the requirement to insert an ‘at’ (or ‘at or above’) altitude restriction at a waypoint positioned on the segment feeding the upper sequencing leg, at least 7nm before the crossing point with the lower sequencing leg.

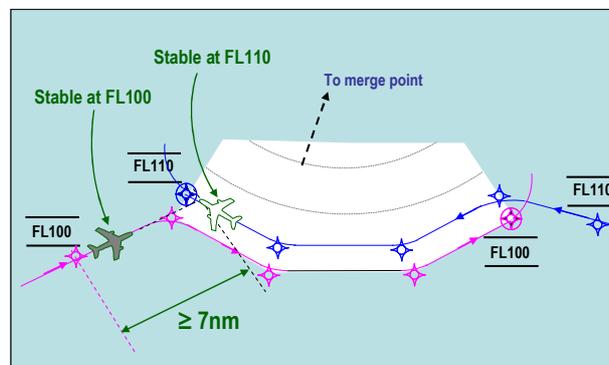
### 12.1.3 Levelling-off below another close parallel sequencing leg

Nuisance RAs might also be triggered, in case of close parallel sequencing legs, by aircraft descending to join the lower sequencing leg, close to another aircraft on the upper sequencing leg (1000ft above). This is illustrated in Figure 12-5.



**Figure 12-5. Nuisance RA – descending towards the lower leg**

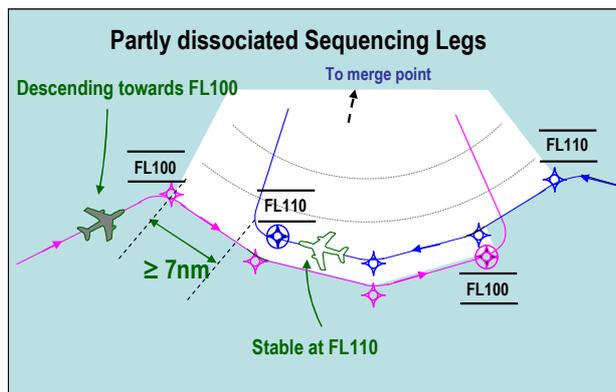
This type of alert can only be prevented by ensuring that the aircraft joining the lower leg reaches its prescribed level at least 7nm away from the upper leg traffic. Again, an ‘at’ (or ‘at or below’) altitude restriction may thus be published on a point appropriately located before the entry of the sequencing leg:



**Figure 12-6. Nuisance RA – descending towards the lower leg: horizontal solution**

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Note: horizontal solutions for minimising the risk of nuisance RAs with Point Merge may also be considered in the case of partly dissociated sequencing legs, as illustrated below:



**Figure 12-7. Nuisance RA – horizontal solution: case of partly dissociated legs**

## 12.2 Traffic presentation vs. Point Merge capacity

As stated in §7.1, the Point Merge procedure normally requires an appropriate metering of arrival flows (at least when applied in approach airspace), so as to reduce the occurrence of sequencing leg run-offs. In that context, a buffer shall be added as an operational margin (i.e. in nominal conditions, only a defined portion of the sequencing legs should be used). This buffer should enable catering for unexpected situations (e.g. missed approach), but also keeping some flexibility (e.g. changing sequence order while already on the legs).

Conversely, subject to airspace constraints, a Point Merge system may have to be dimensioned according to expected traffic demand and traffic presentation characteristics, including the expected level of traffic ‘bunching’. In particular, this would be the case in situations where an accurate pre-regulation of traffic may be difficult to achieve in an efficient manner (e.g. delivery from En Route to E-TMA), and where traffic would only be regulated, with less accuracy, in a more strategic manner, considering traffic flows at the ATM network level.

In any case, it shall be borne in mind that a pre-regulation of traffic adhering to a given metering requirement does not by itself necessarily result in a regular longitudinal spacing of same flow aircraft, and does not in particular guarantee longitudinal separation. Additional traffic presentation aspects may also be covered by e.g. Letters Of Agreement (LoAs). These may impose longitudinal separation (or even an extra spacing) to be achieved before transfer and/or include provisions for inbound traffic to normally enter a sector (hence possibly the Point Merge system) using different flight levels/altitudes. In configurations using close parallel sequencing legs, this may induce the use of more than one level on a single sequencing leg (see §5.2), and be one more reason to allow for a ‘spare level’ as stated above in §6.4.

An AMAN may be used for arrival management in order to support the achievement of an appropriate metering at the Point Merge system’s entry. In that case, It should be properly calibrated according to the Point Merge system’s capacity so that aircraft do not fly more than x% of the length of the sequencing legs in y% of cases; ‘x’ and ‘y’ being parameters which may have to be adjusted locally<sup>85</sup>.

As the Point Merge procedure involves a path stretching capacity that cannot normally be extended (unless radar vectors and/or holds are used to cope with unexpected/non-nominal situations), there may be a higher sensitivity to changes in sequence order after the IAF than with radar vectors; hence an increased risk of sequencing legs run-off if the AMAN sequence order is not adhered to, for whatever reason (although if it is intended to leave a certain flexibility to ATC for the sequence order, an adequate AMAN calibration and dimensioning of the Point Merge system may allow to do so – subject to local constraints).

<sup>85</sup> ‘No more than 66% of the legs for 95% of the time’ would for instance appear as a reasonably protective metering requirement. However the determination of actual values may require a specific study in each case, as they could depend on such aspects as TMA size, local practices regarding use of AMAN, etc...

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Assuming a correctly calibrated AMAN, the AMAN sequence order advisories may be followed by ATC, possibly resulting in a reduction in the ‘sequencing’ task load. On the other hand, if the AMAN sequence is not strictly adhered to, it should be updated (manually or automatically) so as to minimise the risk of confusion, e.g. when instructing the ‘direct-to’ turn.

### 12.3 Terrain/obstacle clearance

Point Merge does not modify the principles governing responsibility for terrain/obstacle clearance.

In particular, being an RNAV procedure, it does not relieve:

- Pilots of their responsibility to ensure that any clearances are safe in respect to terrain clearance.
- ATC of its responsibility to assign levels/altitudes which are at or above established minimum flight altitudes.

However when an Instrument Flight Rules (IFR) flight is being radar vectored by ATC or is given a direct routing off an ATS route, the air traffic controller remains primarily responsible for terrain clearance and shall issue clearances such that the prescribed obstacle clearance exists.

Thus, in Point Merge operation, the controller will be responsible for terrain clearance between the sequencing leg and the merge point in most cases – except for non equipped aircraft, or those that would follow a radio failure procedure or a sequencing leg run-off procedure.

In the case when, within the lateral envelope of possible paths for a Point Merge system, terrain altitude is higher than the altitude of the merge point, clearance(s) should be issued to (an) intermediate level(s)/altitude(s).

Note: without relieving ATC from its responsibility for terrain clearance, it could be envisaged in the future to rely on vertical guidance (e.g. based on range and bearing) between the sequencing leg and the merge point. However, current P-RNAV standard and implementations do not allow for this.

### 12.4 Transition altitude

Currently, transition altitude in Europe varies and can be as low as 3,000ft.

A low transition level/altitude may bear significant drawbacks when it comes to terminal airspace design. In particular, as highlighted in Ref[9] (Part C, §5.4.2), interrupting a descent in the vicinity of a low transition level (i.e. the lowest available flight level above the transition altitude) could result in level busts. A low transition level/altitude also impacts the predictability of the vertical profiles. Vertical restrictions included in a procedure, when expressed in flight levels, will result in different actual altitudes flown above mean sea level/terrain, depending on local atmospheric conditions.

Consequently, the design of a Point Merge system in approach airspace will be affected, should the transition level/altitude be inside its level/altitude range. Indeed, as one of its main constraints in the vertical dimension, any Point Merge design shall ensure that the descent from the sequencing legs FL/altitude to the required altitude (e.g. ILS interception) is possible for all expected aircraft types and conditions, given a defined “distance to go”. As designing the sequencing legs with flight levels<sup>86</sup> induces a dependency of their actual height above terrain on meteorological conditions, sufficient margins need to be included in the procedure in that case to enable the descent in all conditions<sup>87</sup>. Moreover, if the transition level is below the sequencing legs, an interrupted descent might result in misunderstandings regarding the level or altitude the aircraft is currently flying/cleared to, and potentially in level busts – as stated above.

For all these reasons, where possible in case of Point Merge application in approach, the transition level should be above the sequencing legs. This would enable designing the whole Point Merge procedure in altitudes, in a deterministic/predictable manner. This would also enable managing the vertical clearances/instructions consistently between the sequencing legs and the merge point. This recommendation is in line with the current European initiative to raise the transition altitudes to a common value of 18,000 ft. However, it should be noted that such a value may be within the altitude range of a Point Merge system in E-TMA.

<sup>86</sup> I.e. to define a level-off constraint and/or to publish vertical restrictions at the legs start or end points.

<sup>87</sup> A high QNH would result in more stringent constraints on the vertical path – in case of published vertical restrictions above the transition level, as the aircraft would be required to descend with the same track miles, to the same altitude but from a higher altitude above terrain.

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### 13. Annex: Environment definition

This section describes the expected environment at the implementation time horizon (i.e. 2012), in relation with the Point Merge procedure.

#### 13.1 Airspace characteristics

At the 2012 horizon, no changes are foreseen in the key airspace characteristics. For instance airspace classification and separation standards in terminal airspace should remain the same as today.

P-RNAV route structures may be deployed in a significant number of major European TMAs.

The values of typical separation standard should remain 3nm in TMAs (5nm in E-TMA). Subject to local practices, and under certain conditions, the separation in final approach may be reduced to e.g. 2,5nm.

Local airspace characteristics may be influenced by specific aspects such as environment.

#### 13.2 Traffic characteristics

At the 2012 time horizon, a high level (i.e. more than 95%) of P-RNAV equipage – and certification/approval – is assumed. No significant changes in traffic mix which could have an impact on the Point Merge procedure are anticipated otherwise.

Short term traffic increase as compared to today's levels may involve an increase in traffic load between peak periods, and/or the development of secondary platforms and/or new runways.

#### 13.3 Technical characteristics

It is expected that new ground tools will be available at the 2012 time horizon. Some of these tools may not be necessarily required for the initial operation of Point Merge, but could enhance more advanced applications in the future.

#### 13.4 Assumptions

The table below summarises the assumptions for Point Merge operations.

#### Operational Environment Assumptions – Point Merge operations

<b>Overall CNS/ATM Assumptions</b>	
<b>A1</b>	Current ICAO ATC procedures and phraseology (including radar vectoring)
<b>A2</b>	Distance based/ Minimum Radar Separation or Wake Turbulence Separation
<b>A3</b>	Adherence to Terminal Airspace design guidelines (in particular, special attention on flows segregation) (EUROCONTROL Airspace Planning Manual Vol 2, Section 5 – Terminal Airspace Design Guidelines, Ed2.0 – Amendment 1, 17.01.2005)
<b>A4</b>	VHF voice communications between ATC and aircraft
<b>A5</b>	Radar surveillance available (Mode A/C transponder as a minimum)
<b>A6</b>	Current CWP – ECAC average ATCC equipment (paper strip or electronic stripping)
<u>Note:</u> Conformance monitoring tools, such as MONA, are not initially considered as being required although their use might bring additional benefits when they become available	
<b>P-RNAV related Assumptions</b>	
<b>A7</b>	P-RNAV is the enabler for PMS

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**A8** A majority of aircraft are P-RNAV approved (at least 95%)

**A9** A few aircraft may not have Lateral Navigation capability

**A10** A few aircraft may not have direct-to capability

### 13.5 Actors

The following actors are considered in the context of the present OSED.

Role/Actors	Responsibilities
<i>Air Traffic Controllers, including:</i>	
<b>ENR_PLC</b>	En-Route planning controller
<b>ENR_EXC</b>	En-Route executive controller
<b>ETMA_PLC, TMA_PLC</b>	E-TMA (resp. TMA) sector planning controller. Assists ETMA_EXC (resp. TMA_EXC) – Manages coordination with adjacent TMA or Approach sectors and {ACC and/or SEQ}.
<b>ETMA_EXC, TMA_EXC</b>	E-TMA (resp. TMA) sector executive controller.
<b>APP_SEQ</b>	Sequence Manager – Overall management (planning) of the sequence(s) to runway(s), generally with the support of an AMAN, and related coordination with ENR_PLC(s), TMA_PLC(s) or ETMA_PLC(s), APP_PLC(s).
<b>APP_PLC (COO)</b>	Approach planning controller (coordinator) for both APP_EXC and FIN_EXC. In charge of coordination with adjacent sectors in TMA, APP_SEQ and Tower control
<b>APP_EXC</b>	Once inbound flights transferred from the TMA (or E-TMA) sectors, in charge of managing the holding at the IAF if any – or at least the exit from this holding – and starting to build the arrival sequence / prepare traffic integration for FIN_EXC. As an executive controller, He/she has direct radio contact with aircraft under his/her responsibility.
<b>FIN_EXC</b>	Final Director – Executive controller: In charge of finalising the integration of flows into an optimal sequence including proper spacing on final before aircraft are transferred to the Tower controller. He/she has direct radio contact with aircraft under his/her responsibility.
<i>Flight crew, composed of:</i>	
<b>PF (Pilot Flying)</b>	The PF is primarily responsible for the safe operation (including navigation) of the aircraft with regard to terrain, weather, traffic, and aircraft configuration. He/she will call for checklists and charts at the appropriate times.
And <b>PNF (Pilot not Flying)</b>	The PNF monitors the PF, and in addition is responsible for executing instructions from the PF relating to aircraft configuration, programming the FMS, communicating with ATC, administering charts and checklists.

**Table 13-1. Roles and responsibilities**

The figure below shows these actors with respect to the airspace and flight phases as depicted in §16.1.

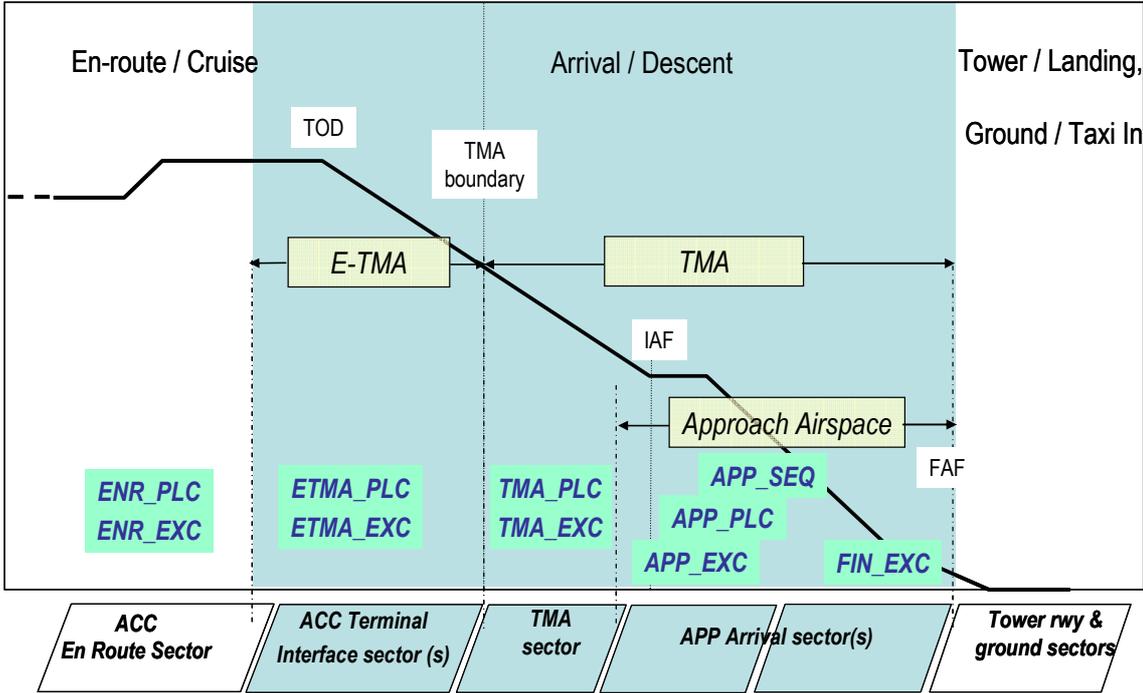


Figure 13-1. Actors in the arrival phase

## 14. Annex: Link with future concept elements

The “Point Merge” method can also be considered as:

- A transition towards extensive use of Performance Based Navigation capabilities and 2D Trajectory Management;
- A sound foundation to support further developments such as advanced continuous descent approaches (3D) and constrained time of arrival (towards 4D);
- A step towards the implementation of airborne spacing (ASAS).

In addition, Point Merge is expected to have the potential to match future runway capacity increases.

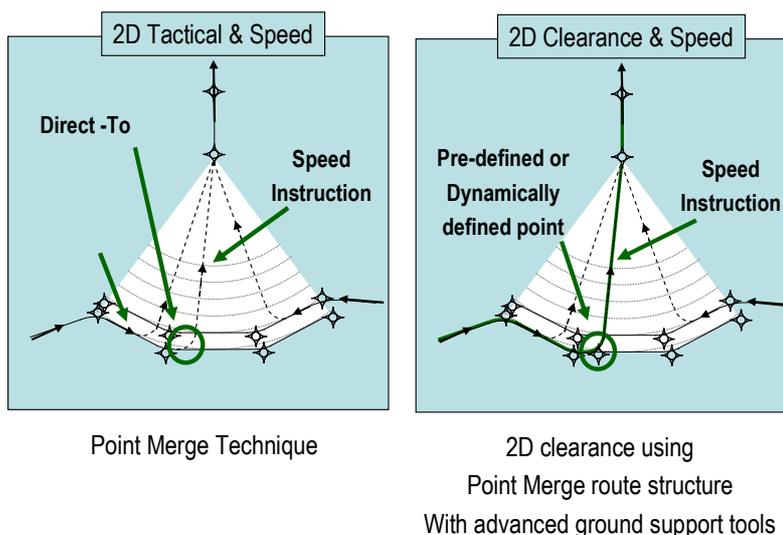
This section provides limited insight on these aspects, which are expected to be developed in separate documents, in support of mid-term concepts validation activities. Related SESAR OI steps can be found in §15.

### 14.1 Matching future runway capacity increases

Future Airport concepts aiming at maximising the runway throughput (Ref SESAR OI L10-05) are expected to result in a reduction of runway separation. Initial validation has shown that the Point Merge technique was usable and acceptable from the controller’s perspective when applying reduced separations in simulated conditions involving up to 50 landing aircraft per hour on a single runway. In other words, not only does Point Merge enable reaching the same spacing accuracy as in today’s operations with vectors, but it is not anticipated that it would be a limiting factor for operations with such an increased runway acceptance rate.

### 14.2 Towards 2D Trajectory Management and Advanced Continuous Descent

In the frame of future Point Merge improvements, with the support of advanced ground tools, it may become possible to provide tactical direct-to turn advisories to the controllers, and/or compute and maintain a ‘distance to go’ estimate before the aircraft are instructed to turn ‘direct-to’ the merge point. Eventually, the turn point towards the merge point might be dynamically determined with a sufficient look-ahead time, enabling an individual route allocation – moving from a tactical 2D closed loop vector to a more strategic trajectory clearance, as illustrated in Figure 14-1 below. In this context, it is anticipated that Point Merge route structures will also support Trajectory Management and Precision Trajectory Clearances as envisioned by the SESAR ConOps (Ref [48]).



**Figure 14-1. From Point Merge to trajectory clearances**

It shall also be remarked that although Point Merge does not rely on RNP capability, it could take advantage of some of its features. For instance, vertical containment capability or fixed radius turn capability (see §8.2)

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could enable more efficient lateral and/or vertical profiles; aircrew alerting in case of deviation could bring additional safety benefits.

Finally, as already stated above, the initial validation of Point Merge in Approach has shown benefits in terms of optimisation of vertical profiles through CDA from at least the sequencing legs FL/Altitude, to the runway (Cf. Ref [19]). Point Merge has actually the potential for further supporting advanced CDA concepts. In particular, configurations with dissociated sequencing legs would enable an improved vertical profile from a higher FL/altitude. In such configurations, even with no additional tool, CDAs from the IAFs may become possible - although there would remain an uncertainty about the distance to touchdown until the direct-to instruction is issued on a tactical basis (see §5.2.1). In the future, CDAs from closer to the cruise level could be planned, so as to include the whole arrival phase.

### 14.3 Towards 4D Trajectory Management

Future SESAR concepts include the issuance of AMAN advisories in the form of time constraints on a merge point or an upstream metering point (Controlled time of Arrival, or CTA), having precedence on the initial time estimate, and to be applied as early as possible, while flights are still in En-Route or in E-TMA.

In Approach airspace, initial validation of the Point Merge technique has shown that the same level of inter-aircraft spacing accuracy can be reached at the FAF, compared to the use of vectors. In this context, a Point Merge system, aiming at an efficient integration to the runway, could act as a ‘transfer function’ of time constraints. Indeed, by adhering to:

- AMAN sequence order advisories,
  - runway and wake turbulence separation constraints,
- and following a Point Merge procedure, adherence to a CTA placed before the Point Merge system’s entry will actually ‘naturally’ result in adherence to the AMAN-scheduled time at the FAF or runway threshold.

### 14.4 Towards Airborne Spacing applications

Route structures based on Point Merge principles can support future ASAS Airborne Spacing Sequencing and Merging applications, e.g. ‘Follow Route then Merge’. In such procedures, provided the aircraft are suitably equipped<sup>88</sup>, schematically, the time to turn direct-to the merge point, as well as the subsequent speed adjustments would be computed – and possibly managed – by an airborne system, while the whole process would remain subject to ATC instructions and ATC retains the responsibility for separation.

More details and references are available in Ref [32].

<sup>88</sup> i.e. ‘ADS-B out’ as a minimum for the leading aircraft, ‘ADS-B in’ and ASAS logic for the trailing aircraft.

## 15. Annex: Link with SESAR

This section provides traceability to SESAR deliverables. As part of the EUROCONTROL Terminal Airspace Improvements Programme, Point Merge is integrated into the SESAR (IP1) timeframe.

### 15.1 Deliverable 1 – The Current Situation

The table below shows the relationship between some blocking points identified in SESAR D1 (Ref [45]) and the Point Merge integration of arrival flows.

Theme	Blocking point	Direct link	Indirect link
<b>Airport Environment</b>	Absence of arrival sequencing tools reduces runway capacity and increases airborne holding		<b>X</b>
	Arrival flow: effective reduction in arrival stream density when operating in a headwind		<b>X</b>
	NOISE – Noise abatement	<b>X</b>	
<b>Airspace Environment</b>	ENV-3 "Use of holding stacks"		<b>X</b>
	ENV-4 "Non optimum 2D Routes"	<b>X</b>	
	ENV-5 "Non optimum flight level"	<b>X</b>	
	ENV-6 "Non optimum speed"		<b>X</b>
	ENV-8 "Unbalanced noise distribution due to neighbourhood pressure"		<b>X</b>
	ENV-10 "Locally imposed non -optimal operations"		<b>X</b>
	ENV-11 "Too close airports"		<b>X</b>
	ENV-13 "Non optimal airspace design"		<b>X</b>
	ENV-14 "Non optimal operations"		<b>X</b>
	OPS-2 "Local route network design and utilisation solutions ignoring network impact"		<b>X</b>
	OPS-5 "Appropriate development of TMA structures"	<b>X</b>	
	OPS-17 "Management of critical events, including bad weather at airports"		<b>X</b>
	OPS-21 "Traffic Synchronisation"		<b>X</b>
	OPS-24 "Devt/Impl of local/network Capacity/operational plans"		<b>X</b>
	OPS-26 "Limited potential of traditional means to deliver additional capacity to improve European ATM performance and achieve agreed targets"		<b>X</b>
	OPS-35 "Implementation of P-RNAV"	<b>X</b>	
	LEG-8 "Environmental impact of airspace change"		<b>X</b>
	LEG-15 "RNAV equipage display in a mixed traffic environment"		<b>X</b>
	LEG-16 "RNAV track flexibility"	<b>X</b>	
	LEG-17 "RNAV hold design guidance"		<b>X</b>
LEG-18 "Open Loop ATC vector Instructions"	<b>X</b>		
EFF-1 "Horizontal & vertical flight efficiency"	<b>X</b>		
SAF-3 "Air-ground communications"		<b>X</b>	

### 15.2 Deliverable 2 – The Performance Targets

Among the four KPAs related to the SESAR vision as described in Ref [46] , the Point Merge integration procedure is expected to address particularly Capacity, Flight Efficiency, Predictability, Environment, and Safety.

### 15.3 Deliverable 3 – The Target Concept

The SESAR CONOPS (Ref [48], §D.7) states that “*Controller task-load per flight is a major factor in airspace capacity. The SESAR concept will increase capacity by reducing the requirement for tactical intervention. In highly congested areas dominated by climbing and descending traffic flows this will be achieved by deploying route structures that provide a greater degree of strategic de-confliction and procedures that capitalise on the greater accuracy of aircraft navigation.*”

It further states (§F.3.3, High Complexity Terminal Operations): “*High-complexity terminal operations will feature separated 3D departure routes and 3D arrival routes the vertical component of which may be defined by either:*

- *Level windows for crossing points (3D ‘cones’ with min/max levels) enabling aircraft to fly closer to optimum trajectories when traffic complexity allows, or*

· Vertical containment with aircraft being required to fly within ‘tubes’ to focus on the runway and airspace throughput when traffic complexity is high.

[...]

Multiple 3D arrival routes may include curved route segments and will converge through successive merging points for each runway. The number of merging points and proximity to the runway will depend on the distribution of traffic flows and environmental constraints”. Configurations with single or multiple merging points are further illustrated in the same section.

Finally, in §F.3.5 “Medium/low complexity operations” the CONOPS mentions the fact that “In a medium/low complexity terminal areas aircraft will, as far as possible, fly their individual optimum climb or descent profiles. This will be a Continuous Climb Departure or a Continuous Descent Approach (CDA) with curved segments as required for noise abatement.”

In addition Ref [48], appendix 2 also identified a number of research topics, among which the one below which is closely related to the Point Merge technique:

‘41 Evaluation of terminal route structure design involving alternative arrival techniques with multiple or single merging points.’

#### 15.4 Deliverables 4 & 5 – The Deployment Sequence, and The SESAR Master Plan

With the purpose of supporting the development of D4 (Ref [49]), a list of Operational Improvements (OIs) has been defined, ordered along Lines of Changes and categorised into Implementations Packages (IP1 to IP3). D5 (Ref [50]) further organised these IPs into a refined deployment and R&D roadmap, decomposing each IP into two ATM Capability / Service levels (SL0 to SL5).

*Note: this section actually takes input from the latest changes at the date the present document was issued, as per the electronic version of the Master Plan, available from: [www.atmmasterplan.eu](http://www.atmmasterplan.eu).*

The following SESAR OI steps are of particular relevance regarding Point Merge:

Line of Change Code	Line of Change Title	OI Code	OI Title	OI Step Code	IP	SL	OI Step Title	OI Step Description
L02	Moving from airspace to trajectory based operations	L02-07	Enhancing Terminal Airspace	AOM-0601	1	0	Terminal Airspace Organisation Adapted through Use of Best Practice, PRNAV and FUA Where Suitable	Terminal Airspace is adapted in line with the availability of airspace and the capability of aircraft.
L02	Moving from airspace to trajectory based operations	L02-07	Enhancing Terminal Airspace	AOM-0602	1	1	Enhanced Terminal Airspace with Curved/Segmented Approaches, Steep Approaches and RNAV Approaches Where Suitable	P-RNAV SIDs and STARs are increasingly used. RNP-based curved/segmented approaches and steep approaches are implemented to respond to local operating requirements (e.g. terrain or environmental reasons). Where precision approaches are not feasible, reductions in minima decisions with respect to conventional NPA are made it possible through the implementation of RNAV approach procedures with vertical guidance (APV).
L02	Moving from airspace to trajectory based operations	L02-08	Optimising Climb/Descent	AOM-0701	1	0	Continuous Descent Approach (CDA)	Under specific circumstances (low traffic density), simple Continuous Descent Approach (CDA) is used at airport through adapted procedures (no need for further ground system automation).

The following SESAR OI steps are of particular relevance regarding expected future evolutions building on Point Merge, or transitioning from initial Point Merge implementation:

Line of Change Code	Line of Change Title	OI Code	OI Title	OI Step Code	IP	SL	OI Step Title	OI Step Description
L02	Moving from airspace to trajectory based operations	L02-08	Optimising Climb/Descent	AOM-0702	2	2	Advanced Continuous Descent Approach (ACDA)	This improvement involves the progressive implementation of harmonised procedures for CDAs in higher density traffic. Continuous descent approaches are optimised for each airport arrival procedure. New controller tools and 3D trajectory management enable aircraft to fly, as far as possible, their individual optimum descent profile (the definition of a common and higher transition altitude would be an advantage).
L07	Queue management tools	L07-01	Arrival Traffic Synchronisation	TS-0102	1	0	Arrival Management Supporting TMA Improvements (incl. CDA, P-RNAV)	Arrival Management support is improved to facilitate the use of PRNAV in the terminal area together with the use of CDA approaches. Sequencing support based upon trajectory prediction will also enhance operations within the terminal area thus allowing a mixed navigation capability to operate within the same airspace and provide a transition to eventual 4D operations.
L08	New separation modes	L08-04	ASAS Separation	TS-0105	2	2	ASAS Sequencing and Merging as Contribution to Traffic Synchronization in TMA (ASPA-S&M)	The flight crew ensures a spacing from designated aircraft as stipulated in new controller instructions for aircraft spacing. The spacing could be in time or space. The controller remains responsible for providing separation between aircraft. The crew is assisted by ASAS and automation as necessary.

In addition, the SESAR Master Plan links with Point Merge in terms of R&D as follows:

- SESAR identifies for Service Level 1, Line Of Change 02 (Ref [50], p.26) an R&D topic titled "Develop airspace design guidance material for TMA merging techniques based on P-RNAV".
- The electronic version of the Master Plan identifies for both OI steps AOM-0601 and AOM-0602 an R&D need titled "AOM-060x-03: What airspace design guidance material should be developed for Point Merge based on P-RNAV and what guidance should it contain?"
- The electronic version of the Master Plan also identifies for OI step AOM-0702 an R&D need titled "AOM-0702-03 What guidance material is needed to accommodate CDAs with the Point Merge technique?"

Notes:

1. Other potentially relevant OI steps, related to Trajectory Management (RBT revision and updates) and new Separation Modes (e.g. PTC-2D or PTC-3D) are not detailed here above but may be considered as indirectly linked to future Point Merge evolutions:

- CM-0601 Precision Trajectory Clearances (PTC)-2D Based On Pre-defined 2D Routes
- CM-0602 Precision Trajectory Clearances (PTC)-3D Based On Pre-defined 3D Routes
- AUO-0302 Successive Authorisation of Reference Business / Mission Trajectory (RBT) Segments using Datalink
- AUO-0303 Revision of Reference Business / Mission Trajectory (RBT) using Datalink

2. L08-04 is titled 'ASAS separation' whereas TS-0105 refers to ASAS sequencing and merging (S&M) as an ASAS airborne spacing and/or airborne separation application (i.e. ASPA S&M or ASEP S&M). Both may be considered here as future developments that could be based on a Point Merge route structure.

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## 16. Annex: Definitions, acronyms and references

### 16.1 Definitions

The following specific terminology is used throughout the document:

#### *Operational service*

The term “service”, or “operational service” in the context of this document refers to “a set of related Air Traffic Management transactions, both system supported and manual, which have a clearly defined operational goal and begin and end on an operational event” (Ref [5]).

#### *Vectors and vectoring*

Air traffic controllers may have to vector aircraft on their course, e.g. in the frame of a tactical intervention involving a deviation from the planned route for safety reasons, or in a more systematic way – as is often the case in terminal airspace, to sequence aircraft towards the runway(s). “Open-loop” vectors, as opposed to “closed-loop” vectors, correspond to the case when no indication is given as to the duration or limit of the ATC vector instruction, nor how the aircraft will re-join its initial route. Typically, a simple heading instruction is an open-loop vector, while a “direct-to” instruction is a closed-loop vector. Throughout this document, the terms “vector(s)” and “vectoring” without additional indication refer to open-loop vectors.

#### *Separation and spacing*

According to Ref [1], “separation is the generic term used to describe action on the part of air traffic services to keep aircraft operating in the same general area at such distances from each other that the risk of collision is maintained below an acceptable safe level [...] The required separation between aircraft is generally expressed in terms of minimum distances in each dimension which should not be simultaneously infringed”. The term “separation standard” (or “separation minimum”) refers to this required separation for a particular airspace.

Beyond the application of separation minima, larger longitudinal distances may be established between successive aircraft for particular purposes, such as:

- To introduce gaps so as to prepare the integration of traffic flows into a runway sequence,
- To take account of wake turbulence constraints,
- To facilitate departures from the same runway e.g. in case of varied aircraft performances.

In the context of this document, “spacing” refers either:

- To the actual longitudinal/lateral or vertical distance between e.g. successive aircraft<sup>89</sup>;
- To the action of establishing such a distance (desired spacing) between e.g. successive aircraft, for any purpose including, but not limited to, separation;
- Or to the minimum lateral or vertical distance between two route segments;

Under no circumstances shall the desired spacing be below the separation standard for the considered airspace.

#### *Acting on the arrival sequence: sequencing, metering, separation*

Formally, for the purpose of building and maintaining a sequence of arrival flights – to the runway or to an intermediate merging point, the following aspects can be distinguished:

- Sequencing, i.e. ordering flights in the arrival sequence;
- Metering, i.e. regulating the flows in order to anticipate on their subsequent integration according to downstream constraints; and
- Providing separation between aircraft in the sequence – typically when close successive aircraft in the sequence are converging towards the same merge point, and after they merged to that point.

#### Notes:

1. Metering can be applied in a coarse manner at the traffic flow level (i.e. regardless of the sequence order) – typically when inbound traffic starts to build up in excess of downstream capacity during a peak period: systematic speed reductions may be given because there will be a need to delay all flights within the peak to delay the recourse to holding stacks. Metering can also be further applied to flights on an individual basis, taking into account the planned sequence order – typically when a gap needs to be introduced between two aircraft that are merging to an intermediate point, so as to accommodate

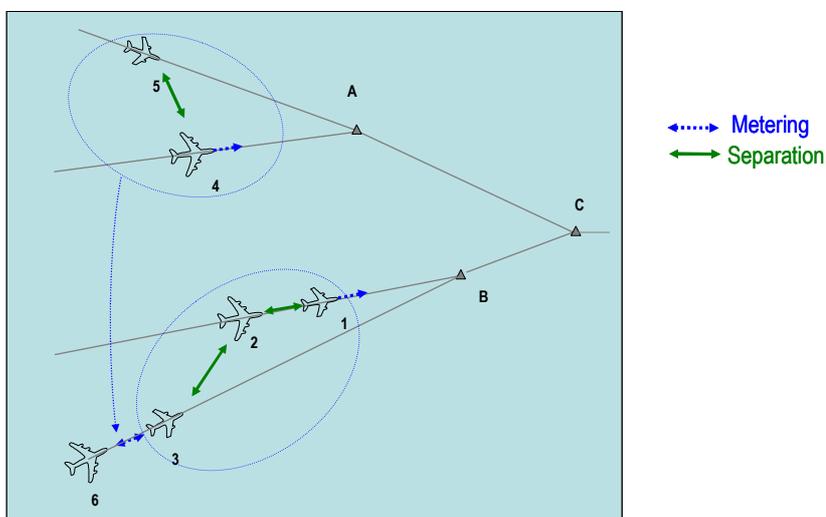
<sup>89</sup> “Actual distance” is generally indeed the meaning of “spacing”, cf. for instance Ref[2], (Chapter 5, §5.2.1.1) “No clearance shall be given to execute any manoeuvre that would reduce the *spacing* between two aircraft to less than the separation minimum applicable in the circumstances.”

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another flow that will be merged later, resulting in a more accurate metering constraint. Such individual measures are typically used at closer ranges from the landing runway, when the sequence is stable enough.

2. Metering does not guarantee separation: two aircraft could arrive at the same time over a point and still adhere to metering constraints – provided it is still possible to separate them before reaching the runway threshold. Conversely, metering may locally require an increased inter-aircraft spacing i.e. beyond the minimum separation.
3. Separation is by essence of a relative nature, and being related to safety, induces stringent requirements on spacing accuracy; whereas metering considers absolute time references, and imposes less constraint on spacing accuracy.

An arrival management tool (AMAN) may help support sequencing and metering aspects by maintaining a global picture of the arrival sequence to the runway(s), and providing advisories to be applied in E-TMA/TMA sectors and/or Approach sectors.



**Figure 16-1. Progressive integration of arrival flows**

In Figure 16-1 above, four flows are successively merged towards point C. The planned sequence order after point B is given by the numbering of the flights. Flights 4 and 5 need to be separated while merging to point A, forming an intermediate sequence. On the southern flow, flights 1 and 2 are already in sequence and have to be monitored for separation. Flight 3 will merge behind flight 2. In order to anticipate on the insertion of flights 4 and 5 into the sequence when merging later with the southern flow to point C, a sufficient ‘gap’ be introduced in front of flights 4 and 6, which involves metering actions.

#### ***Performance –related vocabulary***

Some of the terms designating Key Performance Areas (KPA) are used in the context of this document with a more general meaning than their ICAO or SESAR definition. In particular:

- The “Efficiency” KPA is defined as the “operational and economic cost-effectiveness of gate-to-gate flight operations from a single flight perspective”, whereas efficiency, in the context of the present document, may not be limited to “flight efficiency”, but also cover other context-dependent aspects, such as operational efficiency from a ground perspective;
- The “Flexibility” KPA is defined as the “ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times.”, whereas flexibility, in the context of the present document, may also apply to other aspects such as an operational procedure from the ground perspective.

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### ***Lateral and Vertical Navigation***

(Source: EATMP glossary)

Lateral navigation is the function of airborne navigation equipment that computes, displays, and provides lateral guidance to a profile or path. It is generally referred to as “LNAV” by Boeing, and “Lateral Managed mode” by Airbus.

Vertical navigation is a function of airborne navigation equipment that computes, displays and provides guidance to a vertical profile or path. It is generally referred to as “VNAV” by Boeing, and “Vertical (Descent) Managed mode” by Airbus.

### ***Area navigation***

In 1998, **Basic Area Navigation (B-RNAV)** was introduced in the En-Route airspace of the ECAC States. This enabled the route network to be radically re-designed to provide more efficient, direct routes, thereby giving operational, economic, capacity and environmental benefits. The navigation accuracy required was  $\pm 5$ nm, and this could be achieved with equipment of relatively limited capability.

In order to connect the 'new' area navigation-based route network to the airspace around airports, it was now necessary to extend area navigation to these terminal areas. Because B-RNAV could not provide the necessary track-keeping accuracy or required navigation functionality, B-RNAV was not appropriate for the more complex terminal environment. Therefore, a more comprehensive navigation standard was developed, with a requirement for more sophisticated equipment functionality as well as a track-keeping accuracy of  $\pm 1$ nm. This is known as **Precision Area Navigation (P-RNAV)**.

The introduction of P-RNAV at airports across the ECAC States allows operations, based on a common set of design and operational principles, to ensure consistent levels of flight safety. The enhanced predictability and repeatability of P-RNAV procedures leads to efficiency and environmental benefits being afforded to both airspace users and air navigation service providers.

**Required Navigation Performance (RNP)** is defined as a statement of the navigational performance necessary for operation within a defined airspace. RNP-RNAV will be the next major step toward achieving a total RNAV environment enabling maximum use to be made of RNAV capability. Track keeping accuracy will be applicable to prescribed RNP values, typically RNP 0.3nm and RNP 0.1nm. No mandate for RNP-RNAV is foreseen before 2010 (and implementation of RNP-RNAV applications not before 2015).

The **Performance Based Navigation (PBN)** concept was recently introduced for harmonization purposes at the ICAO level. In particular, there was a need to address confusion and inconsistencies due to a number of local/regional specific definitions and solutions for RNP/RNAV applications. In addition, where RNP provided a limited statement of required performance accuracy, PBN specifies more extensively RNAV system performance i.e. accuracy, integrity, continuity, availability and functionality.

PBN is divided along:

- ‘RNAV x’ specifications, which do not require on-board performance monitoring and alerting;
- ‘RNP x’ specifications, which do require these functions.

The 'Performance Based Navigation Manual' (Ref [4]) replaces the 'Manual on Required Navigation Performance (RNP) ICAO Doc 9613-AN/937'. Formally, under the PBN concept, P-RNAV corresponds to ‘RNAV 1’.

### ***Continuous descent approach, advanced continuous descent approach***

The Continuous Descent Approach (CDA) concept aims at environmental or flight-efficiency benefits (reduction in noise and gaseous emissions and in fuel consumption). At present several instances of CDA exist in Europe that are not harmonised. To address this issue, EUROCONTROL has produced a “CDA Implementation Guidance Information” brochure (Ref [14]) with the aim of providing “guidance for the local implementation of a simple and effective CDA technique that does not adversely affect capacity in high-density air traffic situations”. In this document, and in the absence of an internationally agreed definition of Continuous Descent Approach, EUROCONTROL proposes the following: ‘Continuous Descent Approach is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions’.

As local conditions require, CDA procedures as defined in Ref [14] may comprise any of the following:

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- Standard Arrival Routes (STARs) (including transitions) which may be designed with vertical profiles. The routes may be tailored to avoid noise-sensitive areas as well as including the vertical profile and the provision of distance to go (DTG) information;
- The provision of ‘distance from touchdown’ (also referred to as ‘distance to go’ (DTG)) information by ATC during vectoring; or
- A combination of these: STARs being used in low traffic density, and DTG estimates being issued by ATC as and when radar intervention is required, e.g. during busy periods.

ICAO working arrangements are in the process of assessing CDA on a global scale and may also produce CDA guidance.

The term ‘Advanced CDA’ (A-CDA) is generally referring to further developments of CDA, involving RNAV procedures, complemented by appropriate ground support tools to allow their use even in high traffic density situations.

***Fly-by and fly-over waypoints***

There are two different types of waypoints:

- Fly-by waypoints, which require turn anticipation (start of turn before the waypoint) to allow tangential interception of the next segment of a route or procedure;
- Fly-over waypoints, at which a turn is initiated (the aircraft starts to turn onto the next route leg as it passes over the waypoint).

Ref [10], §4.3.2 provides general rules for the creation and use of waypoints for RNAV terminal procedures. As part of these rules, it states that:

- Fly-by waypoints should be used, whenever possible.
- Fly-over waypoints must only be used when operationally necessary.

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## 16.2 Acronyms

A/C, a/c	Aircraft
ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre
A-CDA	Advanced Continuous Descent Approach
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
APP	Approach Centre / Control
ARWP	Agency Research Work Plan
ASAS	Airborne Separation Assistance System
ATM	Air Traffic Management
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
B-CDA	Basic Continuous Descent Approach
B-RNAV	Basic Area Navigation
CDA	Continuous Descent Approaches
CDM	Collaborative Decision Making
CFIT	Controlled Flight Into Terrain
CNS	Communication Navigation Surveillance
CTA	Controlled Time of Arrival
CWP	Controller Working Position
DF	Direct To Fix (RNAV path terminator)
DSNA	Direction des Services de la Navigation Aérienne
DST	Decision Support Tool(s)
DTG	Distance To Go (distance from touchdown)
ECAC	European Civil Aviation Conference
EEC	EUROCONTROL Experimental Centre
EHQ	EUROCONTROL Headquarters
ENAV	Ente Nazionale di Assistenza al Volo
ETA	Estimated Time of Arrival
E-TMA	Extended TMA
ETO	Estimated Time Over
EUROCAE	European Organisation for Civil Aviation Equipment
EXC	Executive Controller
FAB	Functional Airspace Block
FAF	Final Approach Fix
FACF	Final Approach Course Fix
FDPS	Flight Data Processing System
FMS	Flight Management System
FL	Flight Level
FPL	Flight Plan
HMI	Human Machine Interface
IAA	Irish Aviation Authority
IAF	Initial Approach Fix
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IP	Implementation Package (SESAR)
KPA	Key Performance Area
LNAV	Lateral Navigation
LoA	Letter of Agreement
LVP	Low Visibility Procedures
MONA	Monitoring Aids
ND	Navigation Display
NGO	Non Governmental Organisation
NM, nm	Nautical Mile
NOP	Network Operations Plan
OI	Operational Improvement
OSED	Operational Services and Environment Definition
PBN	Performance Based Navigation

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PF	Pilot Flying
PLC	Planning Controller
PMS	Point Merge system
PNF	Pilot Not Flying
P-RNAV	Precision Area Navigation
RA	Resolution Advisory
RBT	Reference Business Trajectory
RNAV	Area Navigation
RNP	Required Navigation Performance
R/T	Radio Telephony
RWY	Runway
S.Leg	Sequencing Leg
SESAR	Single European Sky ATM Research
SEQ	Sequence Manager
SID	Standard Instrument Departure
STAR	Standard Arrival Route
TCAS	Traffic Collision Avoidance System
TMA	Terminal Manoeuvring Area, or Terminal Control Area
TOD	Top Of Descent
TP	Trajectory Prediction
TSA	Temporary Segregated Area
TTA	Target Time of Arrival
TWR	Tower
VNAV	Vertical Navigation
WP	Work Package
WTC	Wake Turbulence Category

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