Point Merge Integration of Arrival Flows Enabling Extensive RNAV Application and CDA

- Operational Services and Environment Definition

EEC/ATC Requirements Cell

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1. Introduction and document information

1.1 Background and intended audience

Point Merge has been developed by the EUROCONTROL Experimental Centre as an innovative technique aiming at improving and standardising terminal airspace operations\(^1\) in a pan-European perspective (systematic use of precision area navigation and continuous descent in high traffic conditions). As it relies on existing technology, it has the potential for implementation in the short term. It is also considered as a sound foundation to support further developments towards the SESAR target concept such as trajectory based operations. Point Merge is being considered for implementation at Oslo (2011), Dublin (2011) and Rome.

Consequently, this document is addressing both short-term and mid-term activities:
- Short term implementation
  - Point Merge is part of the proposed EUROCONTROL Terminal Airspace Improvements programme;
  - The present document should serve as a reference to ANSPs that are considering Point Merge implementation.
- Medium term validation
  - Point Merge is a building block for mid term concepts in the frame of MTV, TMA2010+ and Episode3/SESAR.


Notice to ANSPs:

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 – e.g. Point Merge – 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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\(^1\) As such, it adheres to EUROCONTROL’s Terminal Airspace Design Guidelines (Ref [9]) and guidelines regarding P-RNAV procedures design (Ref [10], [11]).
1.2 Purpose and lifecycle of the document

The “Point Merge” integration technique enables extensive application of RNAV for arrivals in terminal airspace even at high traffic loads – in contrast to both the currently prevalent use of open-loop vectoring, and existing P-RNAV applications (e.g. “trombone routes”). Point Merge will also enable the more widespread use of Continuous Descent Approaches (e.g. during busier periods). In addition, as detailed below, not only is it expected to bring a range of benefits on its own, but it is also considered as a sound foundation for the SESAR concept to build on, in the frame of MTV and Episode 3 Cycle 1.

The present document constitutes the Operational Services and Environment Definition (OSED) related to the application of this “Point Merge” procedure. It is based on EUROCAE WG53 guidance (Ref [27]) 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”. It identifies the (Air Traffic) Services and their intended operational environments as well as the operational performance expectations, functions, and selected technologies of the related CNS/ATM system. In order to further define related operational and performance requirements, it is essential that not only the new operating method, but also the current one be described in the present document.

This OSED is a living document. The present version is issued following initial validation activities (regarding the use of Point Merge in Approach under various conditions). It forms an input to:
- short-term local implementation studies and programmes by ANSPs;
- mid-term validation activities, where additional assessment is required.

The document is expected to be updated where necessary according to the outcomes of these activities. This iterative process 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.

1.3 Status of assessment activities

1. The new procedure described in this document has already been studied and found feasible and beneficial in various configurations, considering a ‘generic’ environment in Approach – i.e. from the IAF to the FAF, as described in §6.1 – (Cf. initial measurement simulations, Ref [16], [17], [18], [19]). Similar results have been obtained through a real-time simulation conducted recently to support local implementation (see #4 below). Validation activities that have been carried out so far include ground prototyping sessions using real-time human-in-the-loop simulations, initial flight deck real time simulations, and model-based simulations. Validation has shown in particular that, in addition to enabling extensive P-RNAV application, initial CDAs from FL100 would already be possible with the new procedure (Ref [16],[18]), subject to local constraints. In addition, specific configurations may enable CDAs from closer to the cruise level (see §5.3.2, 7.1.2, 9.1 and Ref [19]).

2. A ‘Point Merge Procedure Design and Coding Assessment’ has been conducted (Ref [20]), 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”. The latter would involve special attention areas when designing and charting the procedure, or coordination with navigation database providers and FMS datahouses. They are referred to where appropriate in the present document, along with references to the assessment report.

3. The safety assessment has started with the objective of producing a preliminary safety case by end of 2008 (see Ref [22]). Where appropriate, recommendations arising from hazard identification sessions already conducted (Ref [21]) are included in the text.

4. The support to implementation has started in 2007 with three potential candidates: AVINOR (Oslo Gardermoen, planned implementation date: 2011), IAA (Dublin, planned implementation date:
2011); ENAV (Roma Fiumicino, implementation to be confirmed). Depending on assistance required by the concerned ANSPs, this activity could encompass support to Point Merge procedure design, specific real time and fast time simulations as well as hazard identification sessions and safety cases, which are carried out as part of the studies towards local implementations. A real-time simulation has already been conducted for Dublin; real-time simulation activities for Oslo and Rome have also started.

5. Finally, Point Merge might also be applied in E-TMA and/or TMA sectors (i.e. before the IAF, as described in §6.2 and §6.3). This aspect is still under definition and would require further study.

1.4 Document structure

Document body

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

Section 2 details the scope and objective of the operational service.

Section 3 defines the operational context.

Section 4 describes the current procedures for merging arrival flows to the runway.

Section 5 describes the proposed new procedure, including underlying principles, supporting P-RNAV route structure, operating method and sample scenario.

Section 6 provides examples of the application of the Point Merge technique to various contexts.

Section 7 details the main possible variations in the design of the route structure, as well as their expected impact on feasibility, applicability and performance aspects.

Section 8 provides additional guidelines, with respect to ACAS and the link to arrival management processes.

Section 9 gives some insight regarding the link to other (future) concept elements.

Section 10 describes the environment in terms of airspace, traffic, roles and responsibilities, as well as technical characteristics.

Annexes

Annex A (section 11) details how Point Merge relates to SESAR.

Annex B (section 12) provides a sample chart for a Point Merge procedure in Approach.

Annex C (section 13) gives more insight on the Point Merge procedure from the cockpit standpoint.

Annex D (section 14) provides examples of controller’s working position screens.

Annex E (section 15) gives general definitions of terms and lists acronyms and reference documents.
2. Scope and objective

The operational service considered in this document aims to integrate arrival flows of traffic into a safe and efficient sequence without relying on open-loop vectors. It is based on a “Point Merge” integration technique enabling continuous use of RNAV, while:

- Maintaining 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 capacity increases;
- Maintaining, or possibly increasing terminal airspace capacity;
- Improving safety, flight efficiency and predictability;
- Minimising the environmental impact – or optimising it in respect of defined target levels;
- Addressing staffing and qualification (with standard and streamlined controller working methods).

These objectives set out the high level performance expectations of the service.

Point Merge focuses on the arrival phase of flight (cf. §3.1, Airspace and Control Phases), and is expected to be deployable from the year 2012 (corresponding to the “mid-term baseline” in SESAR).

It 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.

The application of RNAV concepts in terminal airspace to the management of departures is outside the initial scope, but should be defined in a later stage (extending this OSED – or complementing it by other individual OSEDs).

Finally, the procedure defined in this document, dealing with 2D improvements for arrivals, is expected to form a sound foundation on top of which further improvements can be envisaged in line with SESAR concepts. Among these are:

- Continuous descent approaches (towards 3D),
- Towards trajectory-based operations in the context of SESAR: introduction of 4D trajectory management (including adherence to an agreed or constrained time of arrival),
- Improvement of spacing accuracy with adapted ground tools,
- Use of pre-defined RNAV routes (ultimately allocation thereof) with advanced ground support/decision tools,
- and at a later stage: ASAS – sequencing and merging.

Notes:

1. Point Merge aims at optimising the use of available airspace – for the integration of flows in busy traffic situations – in terms of capacity, environmental aspects, and where possible in terms of track distance flown.

2. Point Merge is enabling CDAs; due regard should also be given to departures climb out performances (see §7.2.2).
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 and includes the Terminal Manoeuvring Area (TMA), and Approach control. Although it is a rather specific notion, an Extended Terminal Area (ETMA) 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 – leaving the En-Route network – but have not entered the TMA yet.

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

Although formally the TMA encompasses the Approach, in terms of applicability of Point Merge to various types of airspace, we will distinguish between:

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

![Figure 1. Control phases and sectors for the arrival phase of flight](image)

Note: in practice, depending on the local organisation:

- TMA sector controllers, when TMA sectors are defined, 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 corresponds to ‘ACC Terminal Interface’ sectors depicted above.

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3 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]).
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 tasks for the approach controllers (Ref [11], Annex D):

- Departure tasks
  • Separate departures from other departures;
  • Separate departures from arrivals;
- Arrival tasks
  • Separate arrivals from other arrivals;
  • Separate arrivals from departures⁴;
  • Integrate arrivals into an efficient landing sequence to each runway.

Note: Approach air traffic control (ATC) tasks also include:
- Separation from terrain/obstacles (subject to the operational context, according to the ICAO regulation governing responsibility for terrain clearance – see §8.3), and
- Prevention of unauthorized entry into segregated areas.

Integrating (merging) arrival flows requires the ability to expedite or delay aircraft. When traffic demand rises, speed adjustments may not be sufficient and use of path shortening/path stretching techniques may become necessary.

Formally, an “efficient landing sequence” refers both to an optimised sequence order (e.g. according to wake turbulence constraints), and to the achievement of appropriate spacing between flights, both aspects contributing to maintaining the throughput as close as possible to the available runway capacity, while conforming to the separation requirements. This involves:

1. Planning the sequence (i.e. allocate landing runway if needed, and define sequence order);
2. Building the sequence (including order and appropriate spacing);
3. Maintaining the sequence (including optimisation of inter-aircraft spacing).

Due to the progressive nature of the integration of arrival flows, intermediate sequences must generally be built, and traffic flows synchronised⁵ in view of achieving the global sequence towards the concerned runway(s). The three above tasks may apply to an intermediate sequence (typically in E-TMA and/or TMA) or to the final runway sequence (in Approach airspace).

3.3 Precision 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 ±5nm, 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.

⁴ The separation of arrivals and departures is generally facilitated by strategic de-confliction of SIDs and STARs, while the separation of arrivals from other arrivals is often closely related to the building and maintenance of the sequence.

⁵ The SESAR CONOPS (Ref[33]) 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.
with a requirement for more sophisticated equipment functionality as well as a track-keeping accuracy of ±1nm. 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.

3.4 Continuous descent approach

The 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 [13]) 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”. According to this document, as local conditions require, CDA procedures may comprise any of the following:

- 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.
4. Current procedures

4.1 Overview

The progressive merging of arrival flows into a runway sequence is often performed in current day operation through the use of open-loop vectoring, air traffic controllers typically issuing a large number of heading, speed and level instructions. This method is highly flexible; however it results in high workload both for flight crews and controllers\(^6\), 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 is not fully aware of controllers’ intentions when they are vectoring aircraft.

4.2 Conventional operating methods

In E-TMA/TMA sectors, controllers give speed and/or heading instructions as needed to longitudinally separate and/or meter arrivals towards TMA entry points.

Holding patterns 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), controllers further vector the aircraft to fine tune the sequence and integrate traffic flows from different IAFs to the runway axis, in a safe and efficient manner – avoiding unnecessary gaps at the runway threshold. In this context, the strategy followed by controllers for managing arrivals in Approach (with the objective of giving themselves more time and margins to make the implementation and fine tuning of the sequence easier) often results in aircraft flying low and slow; lack of a 2D structure generally leads to intermediate level offs.

4.3 Advanced tools and procedures for arrivals

In some European TMAs, basic 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.

Arrival RNAV procedures have also been defined in the vicinity of some European airports, aiming at airspace capacity, workload, efficiency, predictability and/or environment-related benefits\(^7\). P-RNAV procedures have been designed with the goal of replacing open-loop vectors in Approach for arrivals, and allowing revisiting associated working methods. For instance, “trombone” shaped routes were defined in Frankfurt and Munich. In such procedures the principle is to keep aircraft on their route; the trajectory can be stretched or shortened through pre-defined/fixed route modifications if this is needed for the merging of arrival flows.

However, these 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 [14]), “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

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\(^6\) 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.

\(^7\) It shall be remarked that maximum benefits in all of these areas cannot generally be achieved through a single procedure, and trade-offs have to be considered according to a number of local constraints.
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.”

Finally, regarding vertical profiles, current CDA implementations or field trials consist in:

- either the use of dedicated RNAV procedures – generally only possible in low traffic density situations, e.g. at night;
- or the tactical provision of DTG information by ATC in a vectoring environment, often at low altitudes (e.g. from about 6000ft in London Heathrow), with partial benefits⁸.

Notes:

1. There is a quite obvious 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/CDA) and 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 create the sequence order and achieve the proper spacing on final. The sequence order and spacing are created 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.

⁺ Ref [13]: “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”.
5. Proposed new procedure

**Important note**

Initial validation activities for Point Merge were focused on the integration of flows to the runway, in Approach airspace. Therefore, some of the examples provided below for illustration purposes may relate to this specific context. Nevertheless, the proposed new procedure is described in this section as ‘generically’ as possible. It should be kept in mind that, subject to further assessments, Point Merge might actually be applied in a variety of contexts (i.e. in Approach, in E-TMA/TMA; for separation purposes or metering purposes), which are further detailed in §6.

5.1 Principles

Under the proposed new procedure for integrating arrival flows, the following principles will apply:

1. There will be no change with respect to the ATC goal, which will remain to enable a safe, expeditious and orderly flow of air traffic. It is 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. There will be no change either in the principles governing the responsibility for terrain clearance.

2. The new procedure should seek to decrease the level of tactical intervention, and rely on simple clearances/instructions. In addition to reducing workload, this should diminish the risk of (pilot or controller) errors and misunderstandings, even in high density Terminal Airspace.

3. The objective is to effectively integrate the arrival flows, while keeping aircraft on lateral navigation, even at high traffic loads. In this context, open-loop radar vectors should only be used to recover from unexpected situations.

4. The procedure should also support an improved efficiency of vertical profiles, and ultimately be compatible with, or pave the way towards Advanced Continuous Descent Approach (CDA) concepts.

5. A key principle highlighted in Ref [10] is to keep things simple. The new procedure shall provide the controllers with a structured and intuitive way of building and maintaining the sequence, with possibly no requirement for new tools.

6. Delaying or expediting aircraft (through path stretching/shortening) shall be performed in a more flexible manner than with current P-RNAV applications in TMA based on pre-defined route changes, as depicted in §4).

7. Finally, the procedure should also fit in with well-established air and ground practices and related constraints. In particular, from a cockpit perspective, ‘heads-down’ time should be minimised when aircraft is in the TMA and below FL100.

Based on these principles, the proposed new procedure associates a dedicated route structure (RNAV STARs as defined in §5.3) with a systemised operating method (§5.4) to integrate arrival flows with extensive use of RNAV. It builds on the following key aspects:

- integration of arrival flows is achieved on a common point using ‘Direct To’ instructions;
- path stretching is performed without ATC intervention.

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9 Although the new procedure is expected to be compatible with time-based spacing/separation, which should be considered in MTV Cycle 1.

10 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.”

11 New tools may be considered in future steps, or as part of the 2012 environment but may not be required in a first stage, i.e. in the context of the present concept element.
5.2 Expected benefits, anticipated constraints and associated human factors

5.2.1 Expected benefits

It is expected that the new procedure will bring the following benefits:

Operability, Capacity, Cost Effectiveness
- Efficient integration of arrival flows, and full use of the available runway capacity.
- Increased controller’s ability to manage longer and sustained peaks of traffic.
- Significant decrease in R/T frequency load including avoidance of voice channel congestion; this will result in less time spent in communication tasks, but also in smoother voice communications.
- More controller availability for monitoring tasks.

Operability, Interoperability (Harmonisation)
- Standardisation of arrival operations in a pan-European perspective.
- More specifically, systematisation of working method, as well as better allocation of tasks for the Approach air traffic controllers, and better anticipation in sequence building. This will also allow address staffing and qualification issues. Structuring of the traffic will result in a less complex traffic picture and in a reduction in the number of possible sequence combinations.
- Closed-loop vector instructions issued early (as opposed to late open-loop vectors for integration on an axis): possibly while still flying at or above FL100, with no late trajectory change, resulting in a better integration with flight crew’s working methods as well as enabling the FMS to manage and provide better flight efficiency.
- With the support of a route structure, increased 2D predictability, i.e. more predictable trajectories for the human operators; in particular the flight’s crew situation awareness will be enhanced.
- In Approach, with aircraft following a common path after the merge point, homogeneous/standard ILS intercept (also beneficial to situation awareness for both controllers and pilots, and with less risk of ILS intercept error).

Environment and Flight Efficiency
- Suitably equipped aircraft – although not being kept on their planned RNAV route at all times – remaining in lateral navigation mode even under high traffic load (enabling the continued use of FMS functionality, including the computation of the ‘distance to go’).
- Facilitation of the optimisation of vertical profiles in descent, enabling the widespread use of CDAs even under high traffic load.
- Contained, pre-defined trajectory dispersion – and actually no late dispersion.

Predictability
- Increased predictability enabling more effective CDM with a positive impact on airport turnaround operations.

Safety
- Standardised working methods, increased controllers’ availability for monitoring, better predictability and increased controllers’ and pilots’ situation awareness are all in turn expected to contribute enhancing safety.

5.2.2 Anticipated constraints

The following constraints could result from the implementation of the new procedure:

- Intrinsic constraints resulting from the use of Precision RNAV and route structure combined with closed-loop vectors (Ref [11], §2): database consistency, information on (and display on CWP of) aircraft capability, impact on phraseology, confusion over responsibility for terrain clearance\textsuperscript{12} etc..

\textsuperscript{12} Although ICAO has recently defined that, when a ‘Direct To’ is being followed by the aircraft following an ATC instruction, then the air traffic controller remains primarily responsible for terrain clearance (see §8.3).
- 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 §7.1).
- FMS or ground FDPS route used for computations vs. actual route flown, and resulting potential errors in estimates.
- Applicability to various terminal airspace types – taking into account local constraints (e.g. TMA size, environment, TSAs, complexity of arrival/departure flows).

5.2.3 Associated human factors
Certain human factors aspects will be essential for the safe and coherent operation of the new procedure, especially:

- Acceptability aspects for air traffic controllers related to change in working methods, including:
  - task allocation e.g. between Approach controllers;
  - procedure more flexible than currently defined P-RNAV procedures, but less than open-loop vectoring;
  - method being less demanding, risk of controllers becoming bored or having less job satisfaction and/or being less vigilant.

- Feasibility aspects for air traffic controllers, including:
  - handling of mixed equipage situations;
  - impact on controllers’ team work and co-ordination;
  - risk of controllers’ de-skilling with regards to open-loop vectoring (simulation recurrent training might, in future, be the only way to keep controllers’ skills up to the level required to cope with anomalies, i.e. unexpected/non-nominal situations).

- Acceptability aspects for flight crews related to change in working methods.
5.3 Route structure
The design of the proposed route structure differs from existing RNAV procedures in that rather than aiming to replicate existing vectoring patterns, it is dedicated to supporting the revisiting of the working method, whilst conforming to the principles stated in §5.1 above. Traffic is merged on a point, by analogy with currently existing practices as regards pre-sequencing in E-TMA. General guidelines applicable to terminal airspace and RNAV procedures design (Ref [9], [10], [11]) shall also be taken into account.

5.3.1 The Point Merge system
A “Point Merge system” is a portion of a route structure, enabling the integration of two or more inbound flows into one sequence, and characterised by the features described below.

Merge point
Traffic integration is performed by merging inbound flows to a single point. After this merge point, aircraft are established on a fixed common route until the exit of the Point Merge system.

Sequencing legs..
Before the merge point, a ‘sequencing leg’ is dedicated to path stretching/shortening for each inbound flow. While along a sequencing leg, aircraft can be instructed to fly ‘Direct To’ the merge point at any appropriate time (i.e. be kept for a certain amount of time on the leg for path stretching, or inversely sent early direct to the merge point for path shortening). Sequencing legs have a pre-defined maximum length.

..at ‘iso-distance’ from the merge point
In order for the controller to easily and intuitively determine the appropriate moment to issue the ‘Direct-To’ instructions for each aircraft, based on its spacing with the preceding aircraft in the sequence, and without requiring the support of any new ground tool, the geometry of the Point Merge system shall ensure that:
- aircraft left flying on a sequencing leg are kept (approximately) at the same distance (‘iso-distance’) from the merge point all along this leg (this requirement has an impact on the shape of the sequencing legs, which shall be as close as possible to arcs of circle);
- distinct sequencing legs are (approximately) located at the same distance from the merge point.

5.3.2 Examples
5.3.2.1 Typical Point Merge system
Considering a simple configuration with two inbound flows, Figure 2 below provides a typical example of a Point Merge system:

![Diagram of Point Merge system](image)

Figure 2. Point Merge system – example with two parallel and segmented sequencing legs

13 Such as so-called “trombone” routes.
This Point Merge system is composed of two sequencing legs that are:
- parallel, of opposite directions and vertically separated (see §5.3.3);
- segmented, forming quasi-arcs centred on the merge point (iso-distance requirement).

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

Notes
- Aircraft enter the Point Merge system upon reaching a defined waypoint which will generally be located ahead of the sequencing leg’s entry.
- Aircraft leave the Point Merge system upon reaching a defined waypoint which will generally be located after the merge point.

At this stage, it shall be remarked that the Point Merge procedure is not thought as an open-ended STAR. It should be designed so that if the aircraft reaches the end of the sequencing leg without receiving a ‘Direct To’ clearance (which is not expected to occur under nominal circumstances – see §8.2), it turns automatically towards the merge point as shown in Figure 3 below.

A ‘sequencing leg run-off’ procedure is further detailed in §5.6.2. In the rest of the document, we will always consider the Point Merge procedure as being (part of) a closed STAR. However, for the sake of readability, the figures in this document will generally not include the ‘closing part’ of the Point Merge procedure.

5.3.2.2 Variants
There is actually a wide range of possible variants regarding the geometry and parameters of a Point Merge system, as depicted in §7.1. Still, all these possible options are based on the same high level principles, and are compatible with the proposed operating method described in §5.4. Local constraints may impose specific design choices; conversely, some environments may offer certain flexibility in the design of a route structure supporting Point Merge operations.

In particular, the length of the sequencing legs will directly influence the maximum extent of path stretching. Figure 4 below shows variations in the route structure, considering different path stretching capabilities, with similar lateral dimensions for the global envelope of possible paths – from the left to the right: parallel sequencing legs, shorter and partly dissociated legs or ultimately fully dissociated sequencing legs.
Such variations in the route structures supporting Point Merge could be deployed, 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: such dynamic deployment aspects are still under definition and would require further validation in the frame of local applications.

Figure 5 below provides other examples of Point Merge systems dealing with two inbound flows and comprising two sequencing legs that are:

- shorter, separate (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).

Note: in such configurations, an appropriate lateral separation is required between the end points of the sequencing legs.
5.3.2.3 Impact on vertical profiles

In the first example above (parallel sequencing legs – Figure 2), 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 is not ensured by design. Consequently, the legs will need to be vertically separated (see §5.3.3 below). Different solutions may be envisaged:

- aircraft levelling off when flying along the sequencing legs: this would be the most constraining option. However, even in that case, when leaving the legs, the distance to go (DTG) will be known by the FMS and in case the Point Merge system is located in such a way that aircraft entering it have already reached their TOD, CDAs will already be possible from the level/altitude of the sequencing legs;

- another option would be to define and publish vertical restrictions that would enable aircraft to follow a ‘gentle descent’ along both legs (e.g. from FL130 down to FL110 on one leg, and from FL100 to FL080 on the other one)\(^{14}\). Once instructed to fly ‘Direct To’ the merge point, the vertical profile can be adjusted taking into account the updated DTG information. **Uninterrupted CDAs from closer to the cruise level may become possible.**

In the second example above (dissociated sequencing legs – Figure 5), aircraft flying the procedure are normally expected to be separated longitudinally and/or laterally from each other. Consequently, the vertical separation constraint is released (subject to other local requirements) and aircraft could be in descent at all times while in the Point Merge system\(^{15}\); **more efficient CDAs from closer to the cruise level may become possible** (see also 7.1.2 and 9.1).

5.3.3 Point Merge design guidance: requirements and recommendations

This section provides additional guidance regarding the design of Point Merge systems.

**Note:** some of the general requirements and recommendations below relate to safety. Additional safety recommendations in relation with specific Point Merge contexts can be found in §6.

5.3.3.1 Separation between sequencing legs

1. As a general rule, the design of the route structure shall enable segregation between arrivals from different flows (in addition to strategic de-confliction between arrivals and departures), before the sequence is built\(^{16}\). In particular, sequencing legs shall be appropriately separated in the lateral and/or vertical planes.

2. In case of parallel sequencing legs, due consideration shall be given to the following aspects regarding their lateral separation:
   - they shall not be located too far apart in the horizontal plane, so as to comply with the requirement to be – approximately – at the same distance from the merge point, and thus gain some precision on inter-aircraft spacing when applying the procedure. From this perspective, it is recommended to avoid using a large lateral distance between parallel legs (e.g. equal to, or larger than the required separation);
   - on the other hand, the legs should not be designed too close to each other in order to avoid display cluttering on the controller’s radar screen\(^{17}\).

Therefore a trade-off has to be found, e.g. sequencing legs 2nm apart (which, assuming a 3nm separation standard for instance, also requires the sequencing legs to be vertically separated as stated above).

\(^{14}\) Actually in case of parallel sequencing legs, it might even be envisaged to design one leg with a level off and the other one with aircraft allowed descending. However such a design choice would obviously result in an inequitable management of inbound flows.

\(^{15}\) Provided strategic de-confliction can be used to ensure separation from other flows.

\(^{16}\) Cf. [9], Part C, §5.4.2.

\(^{17}\) Consequently the dimensions of the Point Merge system and/or the sectorisation, having an impact on the zooming level used on the CWP, may also influence the compromise on distance between the sequencing legs (see §7.1.1). With Point Merge systems of small dimensions, 1nm separation between parallel sequencing legs may be sufficient - possibly subject to safety study. It should also be remarked that at later stages, adapted controller decision support tools might alleviate this HMI-related issue.
3. Regarding vertical separation between the sequencing legs, due consideration shall be given to the following aspects:
   - 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 – e.g. each assigned with a different published level/altitude (i.e. at least 1000ft apart), or using appropriate vertical restrictions; consequently, again, in that case a trade-off has to be found.

5.3.3.2 Altitude restrictions
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 [20]).

2. It is further 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 [20]).

3. 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 should be defined for the start and end point of these legs (Ref [20]). Furthermore, if the parallel legs are of opposite direction (as shown in Figure 2), these published vertical restrictions will probably be required in order to minimise ACAS alerts (see also §8.1).

4. Safety recommendation (Ref [21]): in case of parallel sequencing legs, in order to mitigate the risk of an aircraft still being in descent whilst entering the sequencing leg (and therefore allow some time for ATCO to detect a potential level bust), it is recommended that the level restriction be published on a point ahead of the sequencing leg, ensuring that the aircraft levels off prior to entry.
   Note: A similar recommendation also arises in order to minimise ACAS alerts due to the close location of legs start and end points in case of opposite parallel sequencing legs (see §8.1).

The figures below provide examples of published altitude restrictions for a Point Merge system in Approach airspace, in case of close parallel sequencing legs with level-offs, parallel legs with ‘gentle descent’, or dissociated sequencing legs.

In this first example, the aircraft are required to level off along the parallel sequencing legs so as to ensure vertical separation.

‘At’ vertical restrictions are published at the start and end points of the legs, consistently with the recommendation set out in Ref [20].

Note: spare levels may be provisioned e.g. for the lower leg at FL100 and for the highest leg at FL130.

Figure 6. Example: vertical restrictions in a Point Merge system (level off)
In this second example, vertical restrictions are set on the parallel legs so that aircraft from IAF1 will remain below aircraft from IAF2 while along the legs. In both cases however, they may follow a ‘gentle descent’.

Such design may provide a seamless transition between:
- situations where traffic load still enables to follow an efficient vertical path (aircraft do not fly a long distance along the sequencing legs and do not need to level off),
- and situations where the traffic load is such that the need to achieve a safe and efficient runway sequence does not allow anymore the systematic optimisation of individual vertical profiles (aircraft fly longer distances along the legs and reach a point where they may need to level off).

**Figure 7. Example: vertical restrictions in a Point Merge system (‘gentle descent’)***

In this third example, legs are dissociated and aircraft from IAF1 and from IAF2 may follow independently optimised vertical profiles. There is an uncertainty on the ‘distance to go’ until aircraft turn Direct To the merge point, at which time the aircrew can adjust the rate of descent according to the actual remaining distance to touchdown. Vertical restrictions may be published – as pictured here – at the first point of each leg so as to ensure that aircraft turning immediately to the merge point will be able to descend with a shorter DTG.

**Figure 8. Example: vertical restrictions in a Point Merge system (dissociated legs)***

5.3.3.3 Speed restrictions

1. Speed restrictions may also be defined at certain waypoints in a Point Merge system. For instance, if it is the intention of ATC to reduce all aircraft to a common speed when they enter the sequencing leg, 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 [20]).

5.3.3.4 Other charting aspects

1. Waypoints in a Point Merge system (including the merging point) should 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 should be a fly-over waypoint (see §5.6.2).

2. The waypoint names in a Point Merge system shall conform to naming conventions such as those mentioned in Ref [10], §4.3.3. Waypoints on the sequencing legs could be identified using the alphanumeric naming conventions. The merge point should be considered as a strategic waypoint to ATC (see Ref [10], §4.3.1.3, and Ref [20]), and thus be named using 5 letter globally unique pronounceable ICAO Name codes (Ref [10], §4.3.3.6).
3. The Point Merge procedure should be detailed in the AIP, or in a supporting AIC. 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 [20]).

A sample chart is provided in Annex B, including examples of published speed and altitude restrictions.

5.3.3.5 Other design and procedure coding aspects
1. In case of segmented sequencing legs, the maximum anticipated wind conditions should be taken into account when calculating the length of segments in relation with track angle changes at waypoints (see more details in §7.1.1 and Ref [20]).

2. 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 (see Ref [20]).

3. In case of parallel sequencing legs, subject to local constraints, the leg closest to the merging point (‘inner leg’) should nominally have the highest altitude. This enables to clear aircraft for descent earlier after the turn towards the merge point (or even simultaneously, subject to the traffic situation). It also diminishes the risk of separation infringement in case an aircraft descends unexpectedly just after being instructed to turn Direct To the merge point (see details in §7.1.2).

4. Provision shall be made for a spare/additional level (or 1000 feet) for each leg. Such an additional level may be located above or below the considered leg (or possibly between the sequencing legs subject to sufficient vertical segregation). 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 to cope 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 (not expected to be separated using vectors anymore in an RNAV environment).

5. In case holding patterns are defined at (or before) the Point Merge system entry: in order to ensure that aircraft properly enter the sequencing legs when leaving the stacks (i.e. avoid overshoots), the latter should be located upstream from the legs entry points. This may justify the need for an initial route segment before the sequencing leg.

6. A holding pattern might also be defined before the exit of the Point Merge system, e.g. after the merge point; this would allow for instance to deal with situations where a particular aircraft cannot be kept in the sequence anymore (cf. §5.5), or in case of runway closure, without having to systematically send it back to upstream holding patterns.

5.3.4 Combining Point Merge system(s)
RNAV STARs supporting the integration of arrival flows, and conforming to the principles above, can be defined in a specific environment by considering the Point Merge system as a component of the route structure, or as a “building block” thereof. Similarly to the variations in the geometry of Point Merge systems, it should be noted that there is actually a range of possible ways of combining such systems into a route structure, as depicted in §7.1. For instance, the integration of arrival flows in Approach may be supported by a single Point Merge system, or by multiple Point Merge systems, with common or separate merge points, taking in to account local constraints such as the available airspace, route structure in Terminal Airspace, number of IAFs, etc. It might also be envisaged to include successive Point Merge systems in the route structure (but this would require further assessment – see §6.3).
5.4 Operating method

This section provides an overview of the integration of flows using a “Point Merge” procedure. The operating method basically consists of using the combination of an RNAV route (conforming to the design principles defined in §5.3 above) and a closed-loop vector in the form of a “Direct To” instruction to the merge point.

Two main modes are considered for the description of the operating method: normal and abnormal. The normal mode comprises a main flow (nominal cases), and alternative sequences of actions (special cases, including non nominal cases), denoted “alternative flows” below. The main flow is depicted by means of:
- a table detailing steps to be performed by ATC and flight crew for a particular aircraft when it progresses from the entry to the exit of a Point Merge system (§5.4.1);
- a high level scenario, showing in a more dynamic way the application of the procedure to a sequence of aircraft (§5.4.2).

The abnormal mode corresponds to exception handling or service failure cases; it is detailed in §5.5.

5.4.1 Normal mode – main flow: equipped aircraft

Pre-conditions:

General conditions
- Adherence to Terminal Airspace Design Guidelines and/or any other P-RNAV applicable document;
- Arrival and departure flows are strategically segregated;
- ‘Equipped aircraft’ means ‘P-RNAV approved’ (see §5.8 and §10.3);
- Clear indication of aircraft RNAV capability available on CWP.

Entry conditions
- Appropriate arrival acceptance rate(s) set, taking into consideration such issues as wake turbulence constraints, meteorological conditions, metering constraints at the Point Merge system exit (e.g. runway configuration), etc..
- Delivery of metered traffic flow(s) in accordance with this(ese) rate(s) e.g. through an AMAN (see §8.2)\(^{18}\);
- Procedure loaded into FMS and flown by flight crew (with lateral navigation engaged) in accordance with ATC clearance;
- Traffic level is such that systematic sequencing is required.

Post-conditions:

Exit conditions
- Delivery of an integrated and efficient sequence, following a common lateral path.

Main flow: equipped aircraft

Table 1 below provides the high level description of the proposed 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.

As stated in the general conditions above, aircraft equipage refers here to an appropriate level of RNAV capability as defined in §5.8 and aircraft/operator approval.

\(^{18}\) These metering conditions are actually specific to the application of Point Merge in Approach.
<table>
<thead>
<tr>
<th>Step</th>
<th>ATC</th>
<th>Flight crew</th>
<th>Notes</th>
<th>Phase (high level ATCO tasks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check /confirm sequence order</td>
<td></td>
<td>This can be done by using a simple graphical tool (iso-distance markings along the initial legs and sequencing legs).</td>
<td>Prepare &amp; plan the sequence</td>
</tr>
<tr>
<td>2.</td>
<td>Check speed and if required instruct new speed, before the aircraft enters the sequencing leg.</td>
<td>Implement speed instruction before entering the sequencing leg or when entering the leg. Fly the aircraft along the sequencing leg according to the procedure (with lateral navigation engaged).</td>
<td>Speed reduction may be required in order to ensure spacing/separation along the legs, and/or to achieve homogeneous speed profiles before issuing the 'Direct To', and/or for overall regulation purposes. Such speed reduction should be instructed before the aircraft enters the sequencing leg (so as to maximise the time spent on these legs in case of high traffic load).</td>
<td>Build the sequence</td>
</tr>
<tr>
<td>3.</td>
<td>Decide when to issue the Direct To instruction, by anticipating when the required spacing behind the preceding aircraft in the sequence will be achieved.</td>
<td>Required spacing could be affected by wake vortex, meteo, etc..</td>
<td>Maintain the sequence</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Issue Left/Right Direct To merge point when the aircraft has the required spacing behind the preceding aircraft in the sequence.</td>
<td>Implement the ‘Direct To’ the merge point (with lateral navigation engaged).</td>
<td>Monitoring of spacing with preceding aircraft can be done by using a simple graphical tool (range ring centred on merge point, and/or supportive video mapping). There may be situations where multiple Point Merge systems are in operation (see §6.1.2, §7.1.3). In such cases, the preceding aircraft in a particular sequence may be located in a different Point Merge system.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>When clear of other traffic, and when/if appropriate according to altitude/level window at merge point (or at the Point Merge system exit): issue descent clearance.</td>
<td>Manage the descent according to the clearance (with lateral navigation engaged). Flight crew may optimise the descent, as the distance to go is known by the onboard navigation system.</td>
<td>When issuing descent clearance, particular consideration should be given to ensure safe separation from traffic on parallel sequencing leg(s). Depending on Point Merge design, the descent clearance may be issued earlier (see §5.4.3, Alternative flows).</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Use speed control to deliver the aircraft at an optimised spacing and at an appropriate speed for merge point exit.</td>
<td>Implement speed instruction(s) while flying Direct To the merge point, then following the procedure until its last point (with lateral navigation engaged).</td>
<td>Monitoring of spacing with preceding aircraft can be done by using a simple graphical tool (range ring centred on merge point, and/or supportive video mapping).Required spacing could be affected by wake vortex, meteo, traffic from other Point Merge system(s), etc.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Operating method: normal mode, main flow
The description of the Point Merge operating method above is valid whether the preceding aircraft in the sequence is equipped or not. It is expected that non-equipped aircraft will be instructed so as to follow trajectories similar to those flown by equipped aircraft (see §5.4.3).

Some lower level tasks or sub-tasks are not explicitly mentioned in Table 1, although they are expected to be implemented as today. In particular:
- monitoring tasks involved in various steps are not detailed;
- separation assurance remains a controller task but is not explicitly mentioned in Table 1 as it is not specific to the Point Merge operation.

Finally, note that diagrams in the last column in Table 1 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.

### 5.4.2 Scenario “talk-through” for the Point Merge operating method (normal mode)

This section provides a 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. Aircraft remain in level flight on the sequencing legs with the outer leg nominally 1000ft below the inner leg\(^{19}\). 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.

\(^{19}\) This design choice, compared to an outer leg that would be the highest, offers flexibility and safety benefits (Cf. §7.1.2).
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.

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.
Important notes:

1. **The issuance of the “Direct To” instruction** (step 4) is central to the Point Merge technique and its performance aspects: at this stage, both the sequence and an initial spacing are established. It may be necessary to include some margin in spacing with the preceding aircraft when issuing the ‘Direct To’ instruction, in order to:
   - subsequently enable efficient spacing adjustments solely relying on speed control (step 6) – this is constrained by the acceptable speed range when flying/descending towards the merge point;
   - and/or 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).

In addition ATC should take into account the aircraft turn performance so as to ensure safe separation with the following aircraft (on same sequencing leg).

2. In order that the Point Merge operations achieve the maximum efficiency, **flight crew should implement ATC instructions promptly**. In addition, **timely/appropriate compliance must be confirmed by controller monitoring** (in fact, current radar vectoring operations already require prompt implementation).

3. Depending on the geometry of the sequencing legs (i.e. dissociated legs not requiring level off vs. close parallel legs involving level off – see discussion on vertical profiles in §5.3.2), the descent clearance (step 5 in Table 1) may actually take place before the ‘Direct To’ instruction (step 4). This is depicted as an alternative flow in §5.4.3.

4. **Traffic presentation is a key aspect here.** In contrast to open-loop vectors, the proposed 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 §8.2).

   However, this metering constraint applies globally to the inbound flows. It does not necessarily result in a regular, longitudinal separation of same flow aircraft. Subject to local practices, additional traffic presentation aspects may be covered by Letters Of Agreement (LoAs), which may or may not include provisions for inbound traffic to enter a sector (hence possibly the Point Merge system) using different flight levels/altitudes when longitudinal separation is not achieved. In configurations using close parallel sequencing legs, this would be one more reason to allow for a ‘spare level’ as stated above in §5.3.3.

5. With respect to diagram 2 from the scenario talk-through above, speed reductions prior to entering the sequencing legs also enable to spend more time flying along these legs – i.e. absorb more delay. A trade-off may be needed between using speed values that are acceptable (high enough) after the Direct-To, and still low enough while along the legs, to enable sufficient delay absorption. In case the Point Merge system is used in Approach to integrate arrival flows to the runway after the IAF (see §6.1), 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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5.4.3 Normal mode – alternative flows

Table 2 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).

<table>
<thead>
<tr>
<th>Special or non-nominal case</th>
<th>Concerned steps (Table 1)</th>
<th>Impact on procedure, and/or alternative steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non equipped aircraft</td>
<td>Pre-conditions,</td>
<td>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) 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. 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. Note: flight crews are required to inform ATC if they cannot accept a P-RNAV procedure for which they have been cleared.</td>
</tr>
<tr>
<td></td>
<td>Steps 2 to 6</td>
<td></td>
</tr>
<tr>
<td>Meteorological conditions: strong wind</td>
<td>1, 2, 3, 4, 6</td>
<td>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: - take account of wind effect when assessing the sequence order (step 1 in Table 1 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) - 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). - 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).</td>
</tr>
<tr>
<td>Other meteorological conditions</td>
<td>To be assessed</td>
<td>The effect of other meteorological conditions, on the steps described for the operating method, needs to be assessed. In the worst cases (e.g. cumulonimbus on the merge point), it may be required to use radar vectors for the concerned aircraft (see §5.6.1).</td>
</tr>
<tr>
<td>Sequencing leg run-off</td>
<td>3, 4, 5, 6</td>
<td>In case no “Direct to merge point” instruction is received when reaching the end of the sequencing leg, flight crew shall follow the procedure detailed in §5.6.2 below.</td>
</tr>
<tr>
<td>Missed approach</td>
<td>All</td>
<td>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 §5.6.4 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. The missed approach procedure could bring the aircraft back to one IAF (see Figure 14 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 15 and Figure 16 below). Use of ‘discrete holding’ could also be envisaged (see 5.6.4). Depending on FMS capability, the aircraft may not be able to resume the RNAV procedure, and reversion to radar vectors may be required. This may also be required for other aircraft in the sequence in order to create the gap within a short amount of time.</td>
</tr>
<tr>
<td>Emergency</td>
<td>All</td>
<td>ATC identifies where to integrate the 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. This may require using radar vectors for other aircraft in the sequence in order to create the gap within a short amount of time.</td>
</tr>
<tr>
<td>Degraded airborne navigation accuracy</td>
<td>Any</td>
<td>Flight crew informs ATC; ATC monitors flight; if necessary uses radar vectors for this aircraft (see §5.6.1), and treat it as a non-equipped aircraft.</td>
</tr>
<tr>
<td>Special or non-nominal case</td>
<td>Concerned steps (Table 1)</td>
<td>Impact on procedure, and/or alternative steps</td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Loss of airborne RNAV capability</td>
<td>Any</td>
<td>Flight crew informs ATC: ATC uses radar vectors for this aircraft (see §5.6.1), and treat it as a non-equipped aircraft.</td>
</tr>
<tr>
<td>Radio failure (equipped aircraft)</td>
<td>Any</td>
<td>Flight crew follows published radio failure procedure for equipped aircraft (see §5.6.3).</td>
</tr>
<tr>
<td>Radio failure (non equipped aircraft)</td>
<td>Any</td>
<td>Flight crew follows published radio failure procedure for non-equipped aircraft (see §5.6.3).</td>
</tr>
<tr>
<td>Speed restrictions embedded in the P-RNAV procedure (see §5.3.3)</td>
<td>2, 6</td>
<td>If maximum speed restrictions are embedded in the Point Merge procedure, they are expected to be defined either before the entry of the sequencing legs, or after the merge point, to enable optimum streaming, provide flight crews with a better awareness of their expected speed profile, and make sure defined maximum speeds consistent with operational constraints at certain locations are not exceeded by flight crews even in case of communications problem. However these restrictions should not replace speed instructions which will remain necessary to ensure optimal spacing or separation in the sequence, thus no impact is foreseen on the Point Merge operating procedure itself. Note: this would result in even less R/T exchanges and tactical instructions – but on the other hand it may still require some monitoring by ATC, and/or the inconvenience of lack of confidence, or of common understanding in the fact that the a/c will actually follow the restrictions as published. In addition, those speed reductions may not be always necessary (e.g. outside peak hours). A proper balance between those two options (i.e. with or without published/fixed speed restrictions) may need to be found.</td>
</tr>
</tbody>
</table>
| Altitude/Level restrictions embedded in the P-RNAV procedure (see §5.3.3) | 5 | Such level restrictions can be defined as an altitude window at the merge point, ‘at’ altitude constraints at the entry/exit of the sequencing legs or ‘at or above’ altitude constraints at the last point of the sequencing legs. They are expected to ensure that aircraft descend with an optimum vertical profile (based on a defined glide slope e.g. 3°), and/or that there is no inadvertent descent while the aircraft is on the sequencing leg –subject to the 2D geometry of the sequencing leg. They should also help ensuring adherence to known local constraints; however, these restrictions should not replace the need for a descent clearance. Alternative to step 5: 
- ATC issues descent clearance according to altitude/level window at merge point (or at the Point Merge system exit). 
- Flight crew manages the descent according to the clearance and level restrictions as published in the procedure. 
Note: this would result in even less R/T exchanges and tactical instructions – but on the other hand it may still require some monitoring and/or the inconvenience of lack of confidence/common understanding in the fact that the a/c will actually follow the published restrictions. A proper balance between those two options (i.e. with or without published altitude restrictions) may need to be found. |
| Early descent clearance – with e.g. dissociated sequencing legs | 5 and before | In case of dissociated sequencing legs, the descent clearance towards 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 – as there would be no structural levelling-off constraint on the sequencing legs. Such an alternative procedure step would support the improvement of vertical profiles, i.e. towards advanced CDAs with Point Merge (see §6.1.3 and §9.1). |
| 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. 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 between arrival and departure flows). |

Table 2. Operating method: normal mode, alternative flows
5.5 Abnormal modes

Table 3 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.

<table>
<thead>
<tr>
<th>Abnormal event or conditions</th>
<th>Concerned steps (Table 1)</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic flow not metered according to appropriate rate(s)</td>
<td>Pre-conditions</td>
<td>Depending on traffic context, ATC may have to 1) temporarily apply sequencing leg run-off procedure (see Table 2), and/or 2) open holding stacks, and/or 3) use radar vectoring (see §5.6.1).</td>
</tr>
<tr>
<td>Incorrect indication of aircraft RNAV capability in the FDPS/on the CWP</td>
<td>Pre-conditions</td>
<td>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 2).</td>
</tr>
<tr>
<td>Aircraft is suitably equipped, but does not follow the cleared procedure</td>
<td>Pre-conditions</td>
<td>ATC monitors and detects non-conformance. If needed uses radar vectors for the concerned aircraft (see §5.6.1) and treat it as a non-equipped aircraft.</td>
</tr>
<tr>
<td>Aircraft does not reduce speed (or is not instructed to do so) or reduces speed too late (or is instructed too late)</td>
<td>2 (speed instruction before entering the sequencing leg)</td>
<td>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 §5.6.1) so as to re-integrate the flight in the sequence.</td>
</tr>
<tr>
<td>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)</td>
<td>4 (Direct To merge point)</td>
<td>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 §5.6.1) so as to re-integrate the flight in the sequence.</td>
</tr>
<tr>
<td>Aircraft turns too early to the merge point (or is instructed too early)</td>
<td>4</td>
<td>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 §5.6.1) for the concerned aircraft.</td>
</tr>
<tr>
<td>Wrong aircraft turns to the merge point (or wrong aircraft is instructed)</td>
<td>4</td>
<td>Subject to traffic load conditions and spacing with preceding aircraft in the sequence, use radar vectors (see §5.6.1).</td>
</tr>
<tr>
<td>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).</td>
<td>6</td>
<td>Use radar vectors for the concerned aircraft (see §5.6.1), and re-insert it in the sequence – if possible before the merge point.</td>
</tr>
</tbody>
</table>
| 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 (descent clearance) | - If descent is initiated too early (i.e. without being instructed to do so), radar vectors (see §5.6.1) 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.  
- 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 turns too early to the merge point (or is instructed too early) | 6 (speed control phase) | In case of too tight spacing, ATC may use radar vectors for the concerned aircraft (see §5.6.1). |
| 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, a/c 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 §5.6.1). |

Table 3. Operating method: abnormal modes
5.6 Associated fall-back procedures

This section details possible fall-back procedures corresponding to various situations mentioned in Table 2 or Table 3 above.

5.6.1 Use of radar vectors

5.6.1.1 Recovery from unexpected situations

In order to recover from a variety of unexpected situations, as explained in §5.4.3 and §5.5 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, and follow two steps:

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);
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, hence resuming lateral navigation.

Applying this method allows the controller to visually distinguish the ‘problem aircraft’ from the other aircraft in the sequence. Figure 9, Figure 10 and Figure 11 below show such an example after ‘blue aircraft’ turned too early towards the merge point, behind ‘green aircraft’.

![Figure 9. Use of vectors: aircraft turns too early](image)

![Figure 10. Use of vectors: aircraft is vectored along a ‘pseudo leg’](image)

![Figure 11. Use of vectors: aircraft is put back into the sequence](image)
5.6.1.2 Non equipped aircraft
As stated in Table 2 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 a ‘radar-based’ CDA (i.e. with provision of DTG estimates by ATC – see Ref [13]), may be carried out with non-equipped aircraft – while equipped aircraft follow a ‘STAR-based’ CDA in a Point Merge system.

Safety recommendation (Ref [21]):
In order to minimise the risk of confusion when using radar vectors in a Point Merge environment, it is recommended that:
- the CWP offer the possibility to highlight aircraft that are not on lateral navigation (e.g. being on a heading towards the merge point);
- the descent altitude be capped in case of radar heading, if needed;
- very clear handover procedures – and contingency procedures (e.g. in case of RNAV loss) – 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).

5.6.2 Sequencing leg run-off
In case no “Direct to merge point” instruction is received when reaching the end of the sequencing leg, flight crews shall follow the procedure depicted in Figure 12 below, i.e. continue the route by automatically turning towards the merge point and maintaining the level used along the legs (or descend according to published vertical restrictions).

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 1;
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.

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\(^{20}\) to the merge point so as to enable

\(^{20}\) see Ref [10]
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 [20]).

Safety recommendation (Ref [21]): In order to mitigate the risk for lateral deviation at sequencing leg run-off (too early, too late, wrong waypoint), with e.g. potential for loss of separation or adjacent airspace penetration, it is recommended to make the end of leg waypoint a mandatory reporting point.

Notes:
1. It is also recommended that an efficient AMAN and associated working method be used so as to avoid too frequent sequencing legs run-off. 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 (see § 5.6.5).
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 13).

![Figure 13. Sequencing leg run-off procedure (fly-by)](image)

5.6.3 Radio failure

The sequencing leg run-off procedure shall be the basis for radio failure procedure for equipped aircraft. The 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 – in that case for “lost comm” aircraft – while ensuring maximum time to manage the traffic\(^\text{21}\).

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.

\(^{21}\)Ref[20]
5.6.4 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 [20]). 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 following options can be envisaged for a missed approach procedure, providing an easy reintegration in the Point Merge system; the choice will be motivated by local operational or environmental constraints.

Option 1: the procedure brings the aircraft back to the IAF. This option has the following drawbacks:

1. it may result in a long distance flown before re-integrating the approach procedure – however vectoring remains possible at any time for early re-insertion into the sequence (with appropriate co-ordination);
2. it might not be suitable in a high density environment (i.e. result in interactions with other flows) or interact with a segregated area.

![Missed approach procedure](image1)

**Figure 14. Missed approach, option 1: back to IAF**

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 level assigned for the missed approach will ensure vertical separation). Re-integration into the sequence would be easier.

![Missed approach procedure](image2)

**Figure 15. Missed approach, option 2a: back to a “pseudo-sequencing leg”**
However it may still require to use additional levels e.g. below the actual sequencing legs which may induce some confusion. 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:

![Diagram showing missed approach with pseudo-legs](image)

**Figure 16. Missed approach, option 2b: back to an inner “pseudo-sequencing leg”**

Option 3: the missed approach procedure design options 1, 2 and 3 depicted here above involve creating a gap in the sequence, hence penalising other flights – especially under high traffic load. To circumvent this issue, another option may be envisaged: using a discrete holding area, so as to re-insert aircraft in the sequence when possible after a go-around, while minimising the penalty on other flights.

![Diagram showing missed approach with discrete holding](image)

**Figure 17. Missed approach, option 3: discrete holding**

### 5.6.5 Holding

The Point Merge procedure is reducing the need for hold, but may not replace it. Holding stacks should be established prior to 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, 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 [20]).

Note: There is currently no provision for specific holding criteria for P-RNAV procedures, therefore holds may be designed either conventionally or RNAV.
Figure 18 below provides an example of holding patterns 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).

![Figure 18. Use of holding stacks according to operational context (example)](image)

5.6.6 Low performance aircraft
In case the traffic includes low performance aircraft (e.g. slow aircraft / general aviation), it may be necessary to 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 upon approaching the merge point). Low performance aircraft that are not P-RNAV approved would then have to be vectored along the specific procedure.

Note: formally, this means that ATC could then have to deal with:
- a) aircraft with standard performance, that are P-RNAV approved: follow the nominal P-RNAV procedure;
- b) aircraft with standard performance, that are not P-RNAV approved: vectors along the nominal PRNAV procedure;
- c) low performance aircraft, that are P-RNAV approved: follow the dedicated ‘low performance’ P-RNAV procedure;
- d) low performance aircraft, that are not P-RNAV approved: vectors along the dedicated ‘low performance’ P-RNAV procedure;

This may become a 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.

5.7 Aircraft perspective and published procedure
From an aircraft perspective, the FMS route associated with the supporting RNAV procedure will:
- only include one merge point;
- correspond to the long route (for safety reasons e.g. in case of RT failure), that is to say:
  - include the full length of the sequencing leg;
  - include a sequencing leg run-off procedure as described in Figure 12 above.

The published procedure shall also correspond to this long route (see Annex B). Annex C provides more insight on the flight crew’s perspective regarding the Point Merge procedure.
5.8 Enablers
This section details the functional capability requirements for both air and ground. A full overview of the expected operational environment is available in §10 below.

5.8.1 Communications
Air-ground communications using radio-telephony will adequately support the proposed procedure. Where air-ground data link will be deployed, it is not expected to meet the time criticality requirements associated with the new procedure and/or considered airspace, even as regards the transmission of such messages as route clearances.

5.8.2 Navigation
Airborne capabilities shall at least include the following functions:
- lateral navigation,
- a “Direct-to” capability,
- navigation database requirements (i.e. memory capacity on older aircraft may be insufficient).

Moreover, it is expected that the (re-)design of route structures in terminal airspace, in order to support the proposed procedure will require the definition of new points, with sufficient design flexibility (e.g. for the merge point(s)). Such flexibility will generally not be brought by relying on conventional navigation; area navigation (RNAV) will thus be required.

P-RNAV fits all these requirements with a +/- 1nm navigation accuracy.

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 §7.1.2 and §9.1).

It is thus anticipated that in order to fly a Point Merge procedure, State regulators will require P-RNAV approval, which includes (cf. Ref [12]):
- airworthiness compliance statement, through e.g. TGL-10 (Ref [29]) compliance statement by Original Equipment Manufacturer, for the aircraft type with delivered navigation system;
- navigation database integrity, in accordance with ED76 (Ref [28]);
- compliance with operational requirements (procedures, crew training, etc.).

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.

Notes:
1. As far as non equipped aircraft are concerned, the lowest common denominator must be assumed; thus a non equipped aircraft will be assumed to lack even a ‘Direct To’ capability.
2. The Point Merge procedure is radar monitored and does not rely on turn containment.

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

5.8.4 Ground systems: controller support tools
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 CWP videomap, and thus may not require new capabilities for the ground system.

A clear indication of aircraft RNAV equipage/capability will also be needed on the controller’s display, 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.). However 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.

The controller’s display should enable the marking of specific aircraft (this function already exists in most recent ATC systems).

The metering of arrival flows prior to their entry in a Point Merge system, which is required with a certain accuracy (see §5.4.1 and §8.1), may be achieved through the use of an AMAN.

Finally, ground-based conformance monitoring tools such as MONA are not initially considered as being required for the new procedure – although their use might bring additional benefits in this context, when they become available.
6. Applications

This section discusses the application of the Point Merge technique for metering or separation purposes, in Approach airspace or in E-TMA/TMA (i.e. respectively after or before the IAF). Separately from the present document, operational scenarios may be developed in order to provide a global picture of how Point Merge could be used in a succession of terminal airspace sectors, in conjunction with existing ground tools such as an AMAN, to achieve the integration of arrival flows.

In current day operations with radar vectors, the sequencing, metering and separation aspects of arrival flows integration are often closely linked. The Point Merge technique, through a structured working method, enables a clearer distinction:

- Sequencing is actually always an integral part of the Point Merge procedure – the controller issues the ‘Direct To’ instruction in the same order as the planned sequence (steps 1 and 3 in Table 1, §5.4.1).
- Subject to the sequence context, it could then be envisaged to use a Point Merge system for separation or metering purposes as appropriate for each flight in the sequence. The difference would lie in the use of spacing criteria of a different value and nature when issuing the ‘Direct To’ turn.

In all the cases depicted below, it is assumed that speed control is not sufficient – at least during traffic peaks – to achieve the sequence with the required spacing at the exit point, so that there is a need to apply a path stretching/shortening technique.

**Important note:** Currently the application of Point Merge to the Approach for separation purposes (see §6.1) has reached a significant level of maturity as a result of i) initial validation activities, and ii) local assessment where it is already considered for implementation; however other applications mentioned here below (metering, or use in E-TMA/TMA – §6.2, §6.3) are still under definition.

6.1 Application to separation in Approach

The application of the Point Merge procedure 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.

6.1.1 Example with two IAFs, one runway and parallel sequencing legs

6.1.1.1 Route structure

This example considers arrival flows from two IAFs towards a single runway, and two close 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 the one depicted by Figure 19 below:

![Figure 19. Application to Approach: example with two IAFs, one runway](image_url)

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22 See §15.1.
Typical dimensions: for parallel sequencing legs defined at FL100-FL120, and flights reaching 6000ft in descent at the merge point (located about 25nm from touchdown), the distance between the sequencing legs and this merge point would be in the range of 20nm.

6.1.1.2 Pre-conditions

In addition to the general conditions and entry conditions identified in §5.4.1 above, the following specific entry conditions apply:

- 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 ensure longitudinal separation between successive aircraft on the same sequencing leg;
- Inbound aircraft are stable at the required altitude at the Point Merge system’s entry (according to published restrictions and/or ATC instruction). This is intended to ensure separation with aircraft on the other parallel sequencing leg.

6.1.1.3 Typical operating method

As far as ground actors are concerned, with two Approach sectors (APP, FIN) each manned by an executive controller (respectively APP_EXC and FIN_EXC)\(^{23}\), and an Approach planning controller (APP_PLC), Table 4 below provides an example task allocation, with reference to the steps defined in §5.4.1, Table 1:

<table>
<thead>
<tr>
<th>Step #</th>
<th>ATC task</th>
<th>Actor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Check /confirm sequence order</td>
<td>APP_PLC and APP_EXC</td>
</tr>
<tr>
<td>2.</td>
<td>Check speed and if required instruct new speed, before the aircraft enters the sequencing leg.</td>
<td>APP_EXC</td>
</tr>
<tr>
<td>3.</td>
<td>Decide when to issue the Direct To instruction.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Issue Left/Right Direct To merge point.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Transfer to FIN_EXC</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>When clear of other traffic, and when/if appropriate according to altitude/level window at merge point (or at the Point Merge system exit): issue descent clearance to ILS interception altitude.</td>
<td>FIN_EXC</td>
</tr>
<tr>
<td>6.</td>
<td>Use speed control to deliver the aircraft at an optimised spacing and at an appropriate speed for merge point exit.</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>After the aircraft exits the Point Merge system, issue ILS interception clearance.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>→ Transfer to TWR runway controller</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4. Task allocation example with parallel sequencing legs**

Notes:

1. This table is only provided as an example. Local considerations may lead to different choices in terms of sectors, manning, task allocation and transfer.
2. With vectoring, 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 in Approach, a geographical ‘transfer of control limit’ may be defined precisely (and may then, if deemed necessary, be materialised on the controller’s HMI with a specific graphical marking).

It is assumed that at first contact, APP_EXC clears the aircraft for the Point Merge procedure. Traffic metering in upstream airspace (to avoid sequencing leg run-off situations), prior to entering the Point Merge system, may be achieved with the support of an appropriately calibrated AMAN.

The time to instruct the ‘Direct To’ turn towards the merge point is determined by considering the relative spacing with the preceding flight in the sequence (once it is already on course to the merge point). The spacing criterion depends on the runway separation to be applied, as well as necessary margins to ensure the

\(^{23}\) See §10.5.
availability of a sufficient speed range for subsequent sequence optimisation through speed control (step 6).

It is thus based on a constant 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 Figure 20 below). Some adaptations will nevertheless be needed to account for WTC separation criteria, and to cater for certain specific conditions (e.g. strong wind).

As a general rule, and as already the case today, APP_EXC shall not transfer to FIN_EXC an aircraft from the outer leg until it is safely separated from traffic on the other leg. This rule has a different impact depending on the vertical design options of the sequencing legs:

- in case the outer sequencing leg is designed as the highest leg, the descent clearance for aircraft leaving the outer leg shall be given only after the aircraft is clear of traffic from the inner leg.

  Safety recommendation (Ref [21]): It is recommended that, in this configuration, the descent clearance be given by FIN_EXC, after the aircraft is transferred by APP_EXC (as illustrated in Table 4 above). A ‘transfer of control/descent limit’ should be materialised on the CWP as a reminder (e.g. in the form of a dotted line, parallel to the inner sequencing leg).

- in case the inner sequencing leg is the highest one (recommended option), aircraft may start descent earlier – or even possibly immediately after leaving any of the sequencing legs (see §7.1.2). The descent clearance (step 5) may then alternatively be given by APP_EXC, and transfer to FIN_EXC may occur after this step.

  Safety recommendation (Ref [21]): If the ‘Direct To’ and the descent clearance are given in the same radio contact, there is a risk that the aircraft starts descending whilst its course is still on the sequencing leg, potentially resulting in a loss of separation with traffic on the parallel sequencing leg. Therefore, it is recommended in that case to use two instructions (as, in addition, QNH will have to be delivered).

In any case, ATC will clear the aircraft for descent towards the ILS interception altitude, which will be the target altitude for the computation of the vertical profile by the airborne system.

6.1.1.4 Post-conditions

As stated above (§5.2.1 and §5.4.1), aircraft will exit the Point Merge system while flying along a common path: the procedure will thus provide homogeneous exit conditions and allow a standard ILS intercept. The ILS clearance will be instructed by FIN_EXC, and the aircraft will intercept the localizer, 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, in case the merge point is offset from the axis, no heading phase is needed provided the intercept angle achieved with the RNAV procedure is within the ILS alignment tolerance window around the axis. The merge point may also be located along the runway axis, subject to local constraints. In case when the merge point is located close to the FACF, co-ordination with the navigation data providers is recommended so as to ensure consistent waypoint use (see Ref [20]).

Note: in this example, the ‘distance to go’ is known and may be updated by the FMS, as soon as the ‘Direct To’ turn is instructed. Therefore, CDAs are already possible, even under high traffic load, at least from the level/altitude of the sequencing leg (e.g. from FL120 with the example dimensions given above, as illustrated in Figure 20). 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 on the one hand, and the need to achieve a safe and efficient sequence – even under high traffic loads – on the other hand.

Ref [16] and [18] provide more details on such application of the Point Merge procedure. Figure 20 is based on a screen capture taken during a real-time prototyping session, showing the application of the Point Merge technique to a sequence of aircraft in Approach. In this example, KAC165 has just been instructed to turn

24 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.

25 Localizer based approaches always include at least an approach entry point called a Final Approach Course Fix (FACF), a Final Approach Fix (FAF), a runway threshold, and a missed approach procedure. Localizer signal reception is assured on the leg from FACF to FAF.
'Direct To' the merge point by the Approach executive controller, a sufficient spacing having been reached with the preceding aircraft in the sequence (RAM340). The controller used a simple graphical tool (range rings centred on the merge point) to assess this spacing. SWR892, preceding these flights in the sequence, just started to descend from FL100.

6.1.2 Example with four IAFs, one runway, two combined Point Merge systems

6.1.2.1 Route structure
This example considers arrival flows from four IAFs towards a single runway, and the combination of two Point Merge systems with a common point, each consisting of two close parallel sequencing legs with a levelling-off constraint. This case would typically involve a route structure as depicted below (see also Figure 32 in §7.1.3).

Figure 20. Application to Approach: example CWP display

Figure 21. Application to Approach: examples with two merge points and ‘same DTG’
Note: alternative examples of route structures supporting Point Merge with 3 or 4 IAFs are described in §7.

6.1.2.2 Pre-conditions
General conditions and entry conditions are similar to those described in §6.1.1 above.

6.1.2.3 Typical operating method
In the above 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 to avoid ‘nose-to-nose’ converging configurations – in case of unexpected situations. Nevertheless, there is some symmetry in the system 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.

Similarly to §6.1.1 above, CDAs are possible from the sequencing leg altitude/level.

The same considerations on actors and task allocation would apply – 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.
- Safety recommendation (Ref [21]): in order to minimise the risk of separation infringement before ILS interception from different merge points, some flexibility should 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).

6.1.3 Improved CDAs with dissociated sequencing legs

6.1.3.1 Route structure
In that configuration, sequencing legs are not parallel anymore, but dissociated 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 §7.1.2), possibly resulting in more stringent metering requirements at the entry of the Point Merge system. Figure 22 below illustrates different configurations with dissociated sequencing legs (same or opposite direction).

![Figure 22. Application to Approach: dissociated legs for improved CDA](image)
6.1.3.2 Pre-conditions
Entry conditions are similar to those described in §6.1.1 above, except that aircraft may already be in descent when entering the Point Merge system.

6.1.3.3 Typical operating method
Actors and task allocation would be the same as in §6.1.1, with the exception that the levelling off constraint along the sequencing legs is released, and the descent clearance 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 from the IAFs, even though there is an uncertainty on the ‘distance to go’, equal to the length of the sequencing legs.

As the full procedure is entered in the FMS, initial vertical profile calculations prior to the ‘Direct To’ turn to the merge point will be based on the ‘longest route’. When flying along the sequencing leg, the aircraft will continue to descend according to this profile. As soon as the ‘Direct To’ turn is entered by the pilot, the FMS can adjust the vertical profile according to accurate ‘distance to go’ information. Appropriate altitude restrictions may be defined in the procedure (e.g. at the first point of the sequencing leg), to influence the vertical profile computations and ensure the feasibility of descent in all cases.

Initial validation has shown that such a procedure would be acceptable from the cockpit and ground standpoints in nominal conditions, with e.g. 15nm long sequencing legs. However, it still has to be further assessed under a range of different conditions – including non nominal situations, and regarding detailed cockpit procedures.

Note: The following comment was made during recent prototyping sessions with air traffic controllers (and would need to be confirmed by further assessments before it is proposed as a safety recommendation): in case of early descent clearance with dissociated sequencing legs, it might be desirable to clear the descent to an intermediate level first, and later to the ILS interception altitude, (without normally impacting the vertical profile) in order to cope 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.

6.2 Application to E-TMA and/or TMA
The use of the Point Merge technique could be envisaged in E-TMA/TMA (i.e. schematically before the IAF), with the same objectives as in Approach airspace – that is to say, path stretching/shortening for separation or metering purposes, while remaining in lateral navigation mode.

There are indeed some similarities between the pre-sequencing of arrivals in some E-TMAs or TMAs in current day operations, and the way traffic is expected to be sequenced in Approach airspace with Point Merge:
- traffic is sequenced on a point (not on an axis as in Approach today);
- two distinct steps are involved: path stretching/shortening followed by speed control in descent (i.e. these are not mixed as this is the case with vectoring in Approach today).

A simplistic approach could be to design the sequencing legs in this context as overlays of typical vectoring patterns used in E-TMA/TMA.

However, such an application of Point Merge is still under definition and would require further validation. In particular, there would be significant differences with the application to Approach airspace and the following aspects would need to be investigated, as depicted below.

6.2.1.1 Pre-conditions
- The route structure in E-TMA/TMA may involve a number of inbound flows to be merged before the IAF, with could mean traffic from multiple entry points joining the same leg at different FLs.
- In addition, inbound traffic will not be metered before entering the Point Merge system, which could be one additional reason to use different FLs when joining a given sequencing leg.
6.2.1.2 Operating method – Sequence building
- Traffic will have different/heterogeneous speed/altitude profiles and performances, which may require achieving speed and altitude compatibility before entering the sequencing legs (and in turn require that those leg be designed slightly before the TOD rather than at sector entry; aircraft with a high cruise FL may also need to perform an initial descent);
- In general, aircraft will fly at higher speed (hence less delay absorption capability for comparable size of sequencing legs). Along the same lines, less airspace will be available; however there should not be any need for more airspace than today; and designing the procedure according to today’s practices in terms of vectoring – possibly resulting in different geometries of sequencing legs – may alleviate the issue);
- By design of the Point Merge route structure, the procedure may nominally include turns where today only the vectored aircraft would have to deviate;
- The procedure may also involve turns with larger track angle changes than in current operations.

6.2.1.3 Operating method – Sequence maintaining
- One or more flow(s) may need to be integrated late. This could result in vectoring in descent. Nevertheless, if the flows are balanced, dissociated legs could enable to avoid level-off; otherwise, a dedicated sequencing leg for the minority flow may be sequenced depending on the main flow (which would then not be impacted while in descent).

6.3 Application to metering
The use of Point Merge for metering purposes in terminal airspace would correspond to an upstream Point Merge system, in a configuration involving successive Point Merge systems as depicted in §7.1.3, Figure 34, where a metering constraint has to be applied on a given flight (typically propagating from the metering conditions at the entry of a subsequent Point Merge system).

This application of Point Merge to metering has not been tested yet, thus it is not considered as being mature and would require further definition/validation.

In particular, the spacing criterion to be used in order for the controller to determine the appropriate time to instruct the ‘Direct To’ turn would have to be dynamically defined on a case-by-case basis – taking into account other flows to be merged in a downstream Point Merge system and more general metering constraints; this might require dedicated ground support tools (e.g. provision of ‘Direct To’ time advisories, or ‘ghost display’ of concerned aircraft in other systems – based on AMAN advisories).
7. Design options and applicability considerations
This section describes the main possible variations in the design of the Point Merge system, as well as their expected impact on applicability, feasibility and performance aspects.

7.1 Design options
Design options are categorised below into three groups:
- the key dimensioning parameters of a Point Merge system (§7.1.1);
- the main geometrical characteristics of a Point Merge system (§7.1.2);
- the combinations of Point Merge systems into a route structure according to various options (§7.1.3).

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.

7.1.1 Dimensioning parameters

Key Point Merge system parameters include:
- the length of the sequencing legs: “Length of S.Leg”;
- the distance between the sequencing legs and the merge point: \(d(S.Leg, \text{merge point})\);
- the distance between the sequencing legs and the last point of the procedure: \(d(S.Leg, \text{exit point})\);
- the altitude(s)/level(s) of the sequencing legs (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: \(S.Leg \text{FL/altitude difference}\);
- the altitude/level window of the merge point: \(\text{merge point FL/altitude}\).

Figure 23. Key dimensioning parameters

Variations in these parameters will have the following impact:
- Increasing the length of the sequencing legs will result in aircraft being able to remain longer on the legs, and thus in an increased delay absorption capacity. On the other hand, with segmented sequencing legs (see §7.1.2 below) longer sequencing legs may also result in increased sensitivity to wind, which effect will be different on each leg segment.

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26 Figure 23 represents a Point Merge system with close parallel sequencing legs, with the design choice of flights being level along these legs. As stated in §7.1.2, the use of dissociated sequencing legs is expected to enable to release the vertical separation (or level-off) constraints.
Increasing the distance between sequencing legs and the merge point will facilitate the maintenance of the spacing through speed control, and will result in a better spacing accuracy at the merge point. This will be beneficial in terms of acceptability of the procedure. It will also make it possible to maintain the runway throughput and operate closer to runway capacity.

However increasing the horizontal dimension of the Point Merge system will naturally result in a larger 2D footprint.

Increasing the altitude of the sequencing legs will be beneficial both to the environment and to flight efficiency (as 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 enable continuous descent (CDA) from higher altitudes/FLs.\(^{27}\)

In any case, the dimensions of the Point Merge system will obviously be subject to the available airspace and/or local constraints (see applicability aspects in §7.2 below).

Notes:

1. In case of segmented sequencing legs, according to Ref [20], “careful consideration to the maximum anticipated wind should be given when calculating the minimum leg length for a particular aerodrome. 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.”

2. In case of parallel sequencing legs, due consideration should also be given to the distance between the legs. As stated in §5.3.3, a trade-off has to be found between:
   - the requirement to be approximately at iso-distance from the merge point – in order to achieve appropriate spacing accuracy when issuing the Direct-To, and
   - the need to avoid display cluttering.

These two aspects are highly dependent from the zooming level used on the CWPs, which in turn is closely linked to the sector size and/or the Point Merge system’s dimensions. 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 safety assessment.

7.1.2 Geometrical characteristics

Point Merge systems geometrical characteristics are mainly depending on:

- the shape of the sequencing legs (see Figure 24 below: straight legs, or segments closer to arcs of circle);
- the relative position of the sequencing legs in the horizontal plane (parallel, closely grouped or dissociated, same or opposite/alternate direction – see Figure 26 below);
- the relative position of the sequencing legs in the vertical plane (i.e. the closest leg to the merge point can be designed at the lowest FL/altitude, and the FL/altitude of sequencing legs increase with the distance to the merge point – or the other way round);
- fixed, pre-defined turning points on the sequencing leg for route changes instead of immediate direct-to instructions.

7.1.2.1 Shape of the sequencing legs

The closer the sequencing legs to arcs of circle (Figure 24 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.

Note: although Point Merge does not require RNP capability, it could take advantage of some of its features. For instance, here, fixed radius turn capability may 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).
7.1.2.2 Relative horizontal position of the sequencing legs

Variations in the relative position of sequencing legs will have the following impact (Figure 26 below):

- Sequencing legs of same direction may enable to accommodate specific configurations such as e.g. three arrival flows with a single Point Merge system. However with three or more close parallel sequencing legs, the decision time to instruct the ‘Direct To’ turn towards the merge point will be significantly reduced if the leading aircraft is on the inner leg and the trailing aircraft on the outer leg.

- Dissociated sequencing legs will remove the vertical separation (or levelling-off) constraint and thus may allow initiating a near-optimal continuous descent from closer to the TOD; however more airspace may be needed\(^\text{28}\), which may in turn make it more difficult to apply in a constrained environment. Such configuration of sequencing legs may also result in increased sensitivity to perturbations, as the wind effect will be different on each leg.

\(^{28}\) Unless a more efficient metering can be applied before aircraft enter the Point Merge system.
7.1.2.3 Angles and symmetry

The following angles can be defined in a Point Merge system:

- the track angle change from the initial segment of the procedure to the first segment of the sequencing leg (\(\alpha\)), as well as 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 track angle change at the merge point (\(\gamma\)) – towards the exit of the Point Merge system.

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\(^{29}\).

The value of \(\alpha (\alpha', \alpha'')\) will mainly be subject to design choices taking account of local constraints. In addition, it shall be remarked that 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 turning towards the merge point.

The maximum value of \(\gamma\) is linked to the distance between the sequencing legs and the merge point, and the length (and shape) of the sequencing legs. Variability in the value of \(\gamma\) may induce spacing variations at the merge point due to heterogeneous turn angles. In order to avoid such spacing variations, it is recommended

\(^{29}\) Ref[10], §6.3.1.3 states that: “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.”
that the segment from the merge point be aligned, as far as possible, with the symmetry axis of the Point Merge system.

**Figure 28. Influence of the geometry on variability in track angle changes**

Finally, 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, $\beta$ will generally be more or less uniformly close to 90 degrees – with a limited impact then. However for long and straight sequencing legs, the value of $\beta$ may be subject to larger variations – i.e. smaller at the beginning of the leg and larger at the end, involving a sharper turn – potentially with a significant impact on inter-aircraft spacing.

### 7.1.2.4 Relative vertical position of the sequencing legs

Designing the Point Merge system with the inner sequencing leg at the highest FL/Altitude would result in the following advantages:

- aircraft – in particular those from the highest leg – may be cleared for descent earlier (see Figure 29), or depending on the lateral/vertical separation between the sequencing legs and/or on the traffic context, even immediately after their turn towards the merge point whatever the leg they come from; the same controller might then issue both the Direct-To instruction and the descent clearance.
- all other things being equal, there would 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);
- there would also be a reduced risk of separation infringement in case an aircraft unexpectedly descends just after being instructed to turn Direct To the merge point.

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30 Although at first glance it may seem more natural to design it the other way round (i.e. the internal leg at the lowest FL/altitude, increasing the FL/altitude of the legs with the distance to the merge point), having in mind constraints imposed by the descent profile from these sequencing legs, on the distance to the merge point.
7.1.2.5 Pre-defined turning points

The use of pre-defined turning points on the sequencing legs (Figure 30 below) will involve a slightly different operating method, result in a better predictability, and would pave the way towards the application of “full” RNAV routes (the pre-defined turning points ultimately defining 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 would thus involve a decrease in acceptability of the working method.
7.1.3 Combination of Point Merge systems
This section describes the main options for the combination of Point Merge systems into a route structure.

7.1.3.1 Single or multiple Point Merge system(s)
Considering the integration of a number of arrival flows through multiple entry points (typically more than three), it may be envisaged to combine multiple Point Merge systems, i.e. each with one merge point, but all having a common exit point. Figure 32 below illustrates a possible route structure involving two Point Merge systems in a symmetrical configuration, supporting the integration of four arrival flows to a single runway.

![Figure 32. Multiple Point Merge systems with full symmetry](image)

After aircraft leave the sequencing legs, the primary means for separation assurance shall be longitudinal spacing. Therefore, although there are two merge points in the route structure considered here, an appropriate spacing between two successive aircraft is expected to be achieved as soon as the trailing one is instructed to fly Direct-To the merge point, even when they are located in different Point Merge systems. In such configurations, it is recommended that symmetry be ensured in the route design. In the above example, this will ease the visual assessment of spacing between two successive flights that would be located in the northern and southern Point Merge systems, having the same distance to go to the common exit point.

In analogy with ILS interception, a vertical separation should be ensured between the two flows converging towards the common point. This will enable to deal with the (non nominal) case when two aircraft from different Point Merge systems would arrive close to this common point in a ‘nose-to-nose’ situation – i.e. without having achieved the required spacing.

In addition, subject to safety assessment, provision should be made for a lateral offset between the two Point Merge systems, without prejudice to the ‘same distance to go’ symmetry requirement mentioned above. This may be achieved by design, i.e. by adjusting the length of legs between the merge points and the common point, as depicted below in Figure 32. 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 (as depicted in Figure 33).
Figure 32. Multiple Point Merge systems – offset with same ‘distance to go’

Figure 33. Multiple Point Merge systems – offset with same ‘distance to go’ (option 2)
7.1.3.2 Successive Point Merge systems

Due to the progressive nature of the integration of arrival flows, it may be envisaged to design successive Point Merge systems in the route structure. These 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 34 below. Note however that such configurations have not been tested and thus are not considered mature yet. In particular, the implications in terms of metering constraints at the exit of upstream systems (i.e. taking account of other flows), as well as spacing criterion to trigger the ‘Direct To’, would need to be assessed.

![Figure 34. Example: options for successive Point Merge systems](image)

Multiple and/or successive Point Merge systems may be envisaged due to specific airspace constraints.31

7.2 Applicability considerations

7.2.1 Overview

Regarding the applicability of the proposed procedure, different terminal airspace configurations are likely to require different solutions, i.e. variants in the geometry of the route structure, still based on those principles detailed above.

In particular, it is anticipated that the design of the supporting P-RNAV route structure / Point Merge system(s) will be determined by relevant Terminal Airspace characteristics, including:

- 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.

To illustrate how the airspace characteristics would determine the design choices, Figure 35 and Figure 36 show two examples with four IAFs 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, 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

31 However it shall be kept in mind that they may result in incompatibilities with ASAS Sequencing and Merging as currently defined (as such configurations could involve numerous changes in ASAS targets, heterogeneous spacing values, difficulty to display the ASAS links on the CWP).
‘Direct-To’, the first case 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 §5.3.3) 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 larger downwind leg. Multiple Point Merge systems as depicted in Figure 32 above would on the contrary result in a more balanced distribution of distance flown between the traffic flows.

Figure 35. Example with four IAFs, one runway, four parallel sequencing legs

Figure 36. Example with four IAFs, one runway, two sets of dissociated legs
Figure 37 shows an example with four IAFs feeding two runways, relying on two Point Merge systems.

Figure 37. Example with four IAFs, two runways, two Point Merge systems

7.2.2 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 38 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.

Figure 38. Example: departure routes
7.2.3  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.

7.2.4  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\(^{32}\). 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.

7.2.5  Multiple runways
In multiple runways configurations, various runway allocation strategies can be used:
- Geographic allocation: this strategy allocates the landing runway according to the arrival flow. It leads to less complex situations in the air, but may result in longer taxi times, depending on the airport terminals taxways and runways layout. With Point Merge operations, this might translate into a Point Merge system dedicated to each runway. Even in that case though, there may remain some flexibility for a limited number of runway allocation changes, which would have to be coordinated in advance with the Approach controllers, and could involve for the concerned aircraft a change of Point Merge system/arrival procedure, and/or the use of vectors.
- Minimum taxi time: in this strategy, the runway is allocated based on the aircraft destination gate/stand, and associated taxi time. It 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.

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).

7.2.6  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.

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\(^{32}\) 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.”
7.2.7 Multi-airports TMAs

In multi-airports TMA, there are generally complex interactions between arrival and departure flows. When designing Point Merge route structures in such environments, lack of airspace may be an issue. Initially, arrivals to secondary airports may still be managed using vectors. This would also help keep controllers vectoring skills to the level required.
8. Additional guidelines

8.1 Minimising ACAS nuisance alerts

The design of Point Merge procedures shall ensure that no ‘ACAS/TCAS hotspots’ are created – and more generally that ACAS nuisance alerts are minimised as far as possible.

8.1.1 Flying along close parallel sequencing legs

In Point Merge configurations involving close parallel sequencing legs of opposite directions, and levelling off along the legs, ACAS nuisance alerts might be triggered if for any reason one aircraft does not remain stable at the leg’s level/altitude. Along these lines, Ref [20] states that “if it is considered necessary, for safety reasons, to keep the aircraft at a specific altitude while it is on the sequencing legs, then altitude restrictions should be published for the start and end waypoints on the leg. This will probably be the case when two parallel opposite direction sequencing legs are used for the same merge point, in order to minimise ACAS alerts”.

However, these altitude restrictions at start and end points of the legs may not be sufficient to prevent all types of undesired ACAS alerts, as discussed below.

8.1.2 Levelling-off below another close parallel sequencing leg

As stated in Ref [20], ACAS nuisance alerts might also be triggered based upon the range/range rate for different altitudes, in case of close parallel sequencing legs, by aircraft descending to join the lower sequencing leg, when another aircraft is close to the end of the upper sequencing leg (typically 1000ft above). This is illustrated in Figure 39.

![Figure 39. ACAS nuisance alerts with close parallel sequencing legs](image)

This type of alert could be prevented by ensuring that the aircraft joining the lower leg reaches the prescribed altitude before it is too close from the upper leg. An ‘at’ (or window) altitude restriction may thus be published on a point located before the entry of the sequencing leg.

Ref [20] further gives the following example: “At FL100, a TA is generated 40 seconds before the expected crossover point and an RA is generated 30 seconds prior. With closing speeds of up to 500kts, this means that aircraft arriving on the lower altitude arc should be at the required altitude by 6NM prior to the first arc waypoint”.

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8.1.3 Levelling-off above another close parallel sequencing leg

Conversely, when an aircraft is descending to join the upper leg, and another is flying level close to the end of the lower leg (typically 1000ft below), an ACAS RA may be triggered due to a high descent rate for the former aircraft – and to level off constraints positioned close to the opposite direction leg.

In order to reduce such ACAS nuisance alerts in 1000ft level off configurations, 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. The EUROCONTROL ACAS Programme further recommends that pilots climb or descend at a rate less than 1000fpm in the last 1000ft to level-off.

In terms of Point Merge procedure design, this may translate into the requirement to insert an ‘at’ (or possibly window) altitude restriction at a waypoint positioned at an appropriate distance before the start of the upper sequencing leg. This would prevent ‘excessive’ vertical rates close to the level-off altitude. As an example, for aircraft descending on a 3 degree slope at 240kts IAS, the appropriate distance for this additional restriction would be approximately 5nm.

8.1.4 Alternative solutions

Alternatively, more drastic solutions such as using partly dissociated sequencing legs would also enable alleviate this issue – provided the start and end points of opposite legs are laterally separated by a sufficient distance. The example below shows a 1000ft levelling off situations, without nuisance alerts, as the last point of the upper sequencing leg would then be laterally offset from the first point of the lower leg.

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33 Cf. Ref[23], Ref[24] and Ref[25] (available from the EUROCONTROL web site), and the EUROCONTROL ACAS Programme recommendation (available from the EUROCONTROL Navigation Domain web site): “[..] when operating within or outside of RVSM airspace, aircraft should be climbed or descended at a rate of less than 1000 feet per minute in the last 1000 feet to level off in order to avoid ACAS alerts, except that pilots shall comply with any climb/descent rates specified in an ATC clearance or instruction […] Additionally, some European States have published regulations in their Aeronautical Information Publications (AIPs) specifying vertical rates, so it is important to refer to relevant AIPs for specific information.”

34 This may need to be confirmed, considering such issues as FMS capabilities and databases requirements.
8.2 Traffic presentation and metering

As stated in §5.4.1, the Point Merge procedure will require an accurate metering of arrival flows, so as to reduce the occurrence of sequencing leg run-offs. In order to keep some flexibility and operational margins, it may even be desirable that under nominal conditions, only a portion of the sequencing legs be used.

In case an AMAN is used for arrival management, it should thus be properly calibrated 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\(^{35}\). The determination of the actual values may require a specific study in each case, as they could depend on such aspects as TMA size, AMAN performance and local practices regarding its method of use, etc.

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).

Provided a correct AMAN calibration is done, 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.

Safety recommendations (Ref [21]): in order to reduce the risk of discrepancy between the AMAN sequence and the actual sequence:
- a procedure for sequence consistency check (AMAN versus actual sequence) should be defined;
- the safety implications of such discrepancies should be stressed during training.

8.3 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 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 routeing 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.

\(^{35}\) ‘No more than 66\% of the legs for 95\% of the time’ would for instance appear as a reasonably protective metering requirement.
Thus, as regards Point Merge operation, the quasi-systematic use of a Direct-To (unless an aircraft follows the radio failure or sequencing leg run-off procedure) means that the controller will be responsible for terrain clearance between the sequencing leg and the merge point in most cases.

This may result in the need to delay a descent clearance after an aircraft has left the sequencing leg, or the issuance of clearances to intermediate levels. Indeed, even in current type of operations, controllers have to take account of minimum altitudes when vectoring traffic.

Moreover, it is impossible, based on current/standard FMS capability, to publish altitude restrictions that would help in mitigating the risk of CFIT in that phase of flight. Indeed when heading direct to the merge point, the aircraft is flying with lateral navigation engaged but is off the published RNAV route. Any intermediate point located between the aircraft position when the Direct-To turn was initiated, and the merge point, has been removed from the FMS route, along with any restriction placed on it (in particular as regards altitude).

Therefore it is yet to be clarified to which extent – and in which form – it could be possible in the future to publish such altitude restrictions (e.g. using distance and bearing ranges defining sectors centred on the merge point).
9. Link to future concept elements

The “Point Merge” method can be considered as:

- A transition towards extensive use of P-RNAV/PBN;
- 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).

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.

9.1 Towards extensive use of P-RNAV/PBN and A-CDA

As already stated above, initial validation of the Point Merge technique in Approach, using parallel sequencing legs, has proved benefits in terms of optimisation of vertical profiles through limited CDA from at least the sequencing legs to the runway (Cf. Ref [16]). Point Merge has actually the potential for further improvements of vertical profiles, and ultimately compatibility with 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 §6.1.3). In the future, CDAs from closer to the cruise level could be designed, so as to include the whole arrival phase.

It shall also be remarked that although Point Merge does not require RNP capability, it could take advantage of some of its features. For instance, vertical containment capability or fixed radius turn capability (see §7.1.2) could enable more efficient lateral and/or vertical profiles; aircrew alerting in case of deviation could bring additional safety benefits.

Finally, 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 RNAV route allocation – moving from a tactical 2D closed loop vector to a more strategic trajectory clearance, as illustrated in Figure 42 below. In this context, it is anticipated that Point Merge route structures will offer compatibility with Advanced CDAs, Trajectory Management and Precision Trajectory Clearances as envisioned by the SESAR ConOps (Ref [33]).

![Figure 42. From Point Merge to Trajectory Clearances](image-url)
9.2 4D Trajectory Management

Future SESAR concepts include the implementation of a Network Operations Plan (NOP) which is expected to be developed through Collaborative Layered Planning processes involving all concerned stakeholders (airlines, airports, ANSPs,..). The NOP will incorporate for each flight up to date 4D trajectory data, including arrival or over flight time estimates (ETO/ETA), which will represent a global agreement between the actors. The trajectory, and thus possibly the arrival time, may be re-negotiated while in En-Route to take account of unpredictable changes (e.g. actual wind profiles, runway availability). From this perspective, it is expected that in the SESAR timeframe, or in the horizon of medium/short time transitions towards SESAR, the management of arrival flows (through an advanced AMAN, with an enlarged horizon) will actually refine the NOP.

AMAN advisories will translate when needed into 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, by adhering to:
- time constraints at Approach airspace entry points,
- AMAN sequence order advisories,
- runway separation constraints.
planned or constrained arrival times will actually ‘naturally’ be adhered to as well in a Point Merge environment aiming at an efficient integration to the runway.

9.3 Supporting future 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:
- the controller identifies that the conditions are met to use the ASAS application;
- upon ATC instruction, the leading aircraft is formally identified as the ‘ASAS target’;
- once the latter is on a direct course towards the merge point, ATC instructs the trailing aircraft (‘subject’ aircraft) to “merge behind target” at the merge point with an appropriate time or distance-based spacing parameter (e.g. 90 seconds or 120 seconds depending on WTCs);
- in order to acquire the desired spacing, the airborne ASAS logic determines the appropriate time for the subject aircraft to turn direct to the merger point (the DIR TO is then either manually entered by the pilot or managed by the airborne system);
- once direct to the merge point, the spacing is maintained through speed adjustments that are similarly computed, and possibly managed by the airborne system.

In summary, in that case 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 [26].

9.4 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 in conditions involving up to 50 landing aircraft per hour on a single runway, without requiring additional ATC staffing. In other words, not only does Point Merge enable to reach the same spacing accuracy as in today’s operations with vectors, but is not anticipated to be a blocking factor for operations with such an increased runway acceptance rate.

\[36\] i.e. ‘ADS-B out’ as a minimum for the leading aircraft, ‘ADS-B in’ and ASAS logic for the trailing aircraft.
10. Environment definition
This section describes the expected environment at the implementation time horizon (i.e. 2012), in relation with the Point Merge procedure.

10.1 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. 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.

10.2 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.

10.3 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.

10.4 Environment summary
The table below summarises the technical assumptions for Point Merge, compared to conventional vectoring procedures.
### Operational Environment Assumptions – Point Merge system versus Radar Vectoring

<table>
<thead>
<tr>
<th>Operational Environment Element</th>
<th>Radar Vectoring Assumptions</th>
<th>Point Merge Assumptions</th>
</tr>
</thead>
</table>
| **Operational procedures (OPS)** | [OPS 1]. Current ICAO ATC procedures and phraseology, including radar vectoring procedures | [OPS 1]. Same, including:  
- ATC clearance for (P-RNAV) procedure  
- RNAV specific phraseology, e.g. aircrews are required to inform ATC if they cannot accept a (P-RNAV) procedure for which they have been cleared |
| **Separation standards (SEP)** | [SEP 1]. Distance based/ Minimum Radar Separation or Wake Turbulence Separation. | [SEP 1]. Same |
| **Airspace & routes design (DESIGN)** | [DESIGN 1]. Either a route structure is defined or at least an initial app segment in the form of magnetic heading | [DESIGN 1]. Appropriate variant(s) of Point Merge route structure applied to the concerned environment. |
| **Airport infrastructure/runway usage (ARP)** | [ARP 1]. Single or multiple runway, mixed mode or segregated mode. | [ARP 1]. Same |
| **CNS/ATM capabilities (CNS/ATM)** | [CNS/ATM 1]. VHF voice communications between ATC and aircraft  
[CNS/ATM 2]. Radar controlled airspace  
[CNS/ATM 3]. Minimum: Conventional NAVAIDS | [CNS/ATM 1]. Same  
[CNS/ATM 2]. Same  
[CNS/ATM 3]. Navigation infrastructure enabling Point Merge System procedure as designed (e.g. suitable combination of conventional NAVAIDS, GNSS, inertial) |
| **Traffic characteristics (TRAF)** | [TRAF 1]. Dense traffic situation; lateral deviations required to integrate traffic during peaks. | [TRAF 1]. Same |
## Operational Environment Element

<table>
<thead>
<tr>
<th>Operational Environment Element</th>
<th>Radar Vectoring Assumptions</th>
<th>Point Merge Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aircraft equipage</strong> (EQUIP)</td>
<td>[TRAF 2]. Application to APP: traffic metering/presentation constraints.</td>
<td>[TRAF 2]. Same, metering constraints adapted to Point Merge System dimensioning.</td>
</tr>
<tr>
<td></td>
<td>[EQUIP 1]. Most aircraft are B-RNAV approved, some are P-RNAV approved</td>
<td>[EQUIP 1]. A majority of aircraft are P-RNAV approved (actual percentage – in the range of 95 or 97% – still to be evaluated)</td>
</tr>
<tr>
<td></td>
<td>[EQUIP 2]. A few aircraft have not lateral navigation capability</td>
<td>[EQUIP 2]. Same</td>
</tr>
<tr>
<td></td>
<td>[EQUIP 3]. A few aircraft have not Direct-To capability</td>
<td>[EQUIP 3]. Same</td>
</tr>
<tr>
<td></td>
<td>[EQUIP 4]. R/T (VHF 8.33) system available onboard</td>
<td>[EQUIP 4]. Same</td>
</tr>
<tr>
<td></td>
<td>[EQUIP 5]. Mode A/C transponder as a minimum</td>
<td>[EQUIP 5]. Same</td>
</tr>
<tr>
<td><strong>ATC centre provisions</strong> (ATC)</td>
<td>[ATC 1]. Traffic metering means/tools/techniques (e.g. AMAN, systematic use of holding)</td>
<td>[ATC 1]. Traffic metering means/tools/techniques (e.g. AMAN, systematic use of holding) required to ensure metering with a certain accuracy prior to entry in the Approach airspace</td>
</tr>
<tr>
<td></td>
<td>[ATC 2]. Current CWP</td>
<td>[ATC 2]. Same, plus (or including):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ATC 3]. Pre-defined set of range rings (or markings) centred on the merge points (could be part of the CWP video map)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ATC 4]. Indication of aircraft RNAV approval status on CWP or paper strip (insertion of letter P in the FPL denoting aircraft is P-RNAV approved)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ATC 5]. Conformance monitoring tools (such as MONA) are not initially considered as being required although their use might bring additional benefits when they become available</td>
</tr>
</tbody>
</table>
10.5 Roles and responsibilities

The following roles and responsibilities are considered in the context of the present OSED.

<table>
<thead>
<tr>
<th>Role/Actors</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Traffic Controllers, including:</strong></td>
<td></td>
</tr>
<tr>
<td>ENR_PLC</td>
<td>En-Route planning controller</td>
</tr>
<tr>
<td>ENR_EXC</td>
<td>En-Route executive controller</td>
</tr>
<tr>
<td>ETMA_PLC, TMA_PLC</td>
<td>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}.</td>
</tr>
<tr>
<td>ETMA_EXC, TMA_EXC</td>
<td>E-TMA (resp. TMA) sector executive controller.</td>
</tr>
<tr>
<td>APP_SEQ</td>
<td>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).</td>
</tr>
<tr>
<td>APP_PLC (COO)</td>
<td>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</td>
</tr>
<tr>
<td>APP_EXC</td>
<td>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.</td>
</tr>
<tr>
<td>FIN_EXC</td>
<td>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.</td>
</tr>
<tr>
<td><strong>Flight crew, composed of:</strong></td>
<td></td>
</tr>
<tr>
<td>PF (Pilot Flying)</td>
<td>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.</td>
</tr>
<tr>
<td>And</td>
<td></td>
</tr>
<tr>
<td>PNF (Pilot not Flying)</td>
<td>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.</td>
</tr>
</tbody>
</table>

Table 5. Roles and responsibilities
The figure below shows these actors with respect to the airspace and flight phases as depicted in §15.1.

Figure 43. Actors in the arrival phase
11. Annex A: 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.

11.1 Deliverable 1 – The Current Situation

The table below shows the relationship between some blocking points identified in SESAR D1 (Ref [30]) and the Point Merge integration of arrival flows.

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

11.2 Deliverable 2 – The Performance Targets

Among the four KPAs related to the SESAR vision as described in Ref [31], the Point Merge integration procedure is expected to address particularly Capacity, Flight Efficiency, Predictability, Environment, and Safety (see §5.2.1 above).

11.3 Deliverable 3 – The Target Concept

The SESAR CONOPS (Ref [33], §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 [33], 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.’

11.4 Deliverable 4 – The Deployment Sequence

With the purpose of supporting the development of D4 (Ref [34]) , a list of Operational Improvements (OIs) has been defined, ordered along Lines of Changes and categorised into Implementations Packages (IP1 to IP3).

The following SESAR OI steps are of particular relevance regarding Point Merge:
The following SESAR OI steps are of particular relevance regarding expected future evolutions building on Point Merge:

<table>
<thead>
<tr>
<th>Line of Change Code</th>
<th>Line of Change Title</th>
<th>OI Code</th>
<th>OI Title</th>
<th>OI Step Code</th>
<th>OI Step Title</th>
<th>OI Step Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L02</td>
<td>Moving from airspace to trajectory based operations</td>
<td>L02-08</td>
<td>Optimising Climb/Descent</td>
<td>AOM-0702</td>
<td>Advanced Continuous Descent Approach (ACDA)</td>
<td>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).</td>
</tr>
<tr>
<td>L07</td>
<td>Queue management tools</td>
<td>L07-01</td>
<td>Arrival Traffic Synchronisation</td>
<td>TS-0102</td>
<td>Arrival Management Supporting TMA Improvements (incl. CDA, P-RNAV)</td>
<td>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.</td>
</tr>
<tr>
<td>L08</td>
<td>New separation modes</td>
<td>L08-04</td>
<td>ASAS Separation</td>
<td>TS-0105</td>
<td>ASAS Sequencing and Merging as Contribution to Traffic Synchronization in TMA (ASPA-S&amp;M)</td>
<td>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.</td>
</tr>
</tbody>
</table>

(Source: SESAR Agreed OIs v1.3)

Notes:
1. Additional 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 Airborne Spacing. In any case, it should be kept in mind that both Airborne Spacing or (at a later stage) Airborne separation may be considered here as future developments that could be based on a Point Merge route structure.
12. Annex B: AIP publication example (sample chart)

Figure 44. Point Merge procedure: sample chart

Note: This example chart was based upon information provided by AVINOR.
It illustrates an example with the publication of altitude and speed restrictions (from Ref [20]).
13. Annex C: Cockpit standpoint

13.1 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 §5.3.2.1 and §5.3.2.3).

Figure 45 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 §5.6.2 recommendations, it should normally be defined as a fly-over point.

![Figure 45. Cockpit view: example 1 – before sequencing leg](image)
Figure 46 shows the ND and PFD as the aircraft enters the sequencing leg, having passed the first point (DW011), and is level at FL070.

![Figure 46. Cockpit view: example 1 – entering the sequencing leg](image1)

Finally Figure 47 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 47. Cockpit view: example 1 – Direct To input](image2)
13.2 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 §5.3.2.2 and §5.3.2.3).

Figure 48 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 §5.6.2 recommendations, it should normally be defined as a fly-over point.

Figure 48. Cockpit view: example 2 – before sequencing leg entry
Figure 49 shows the ND and PFD as the aircraft flies along the sequencing leg at 220kts IAS, passing an intermediate point, and FL114 in descent – having already been cleared to the ILS interception altitude (4000ft).
14. Annex D: Ground standpoint

As a complement to the example controller’s display provided in §6.1.1.3, the pictures below are actual screen captures from real-time prototyping sessions with air traffic controllers, in various ‘generic’ configurations with four entry points.

14.1 Example 1: 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 §6.1.2.1 and §7.1.3.1. 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 50. Controller display example 1: four entry points, one runway
14.2 Example 2: four entry points, two runways

In this example, four entry points are feeding two independent parallel runways in segregated mode. Each runway is associated with a Point Merge system comprising two close parallel sequencing legs with a levelling-off constraint. The two merge points are ‘NATAR’ and ‘STELA’. In this configuration, traffic in each Point Merge system is managed by an approach controller and a final director, before hand-off to the Tower. A continuous descent was already possible from the sequencing legs.

This type of configuration is discussed in §7.2.1.
15. Annex E: Definitions, acronyms and references

15.1 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 distance between successive aircraft;
- or to the action of establishing a longitudinal distance (desired spacing) between successive aircraft, for any purpose including, but not limited to, separation. 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 globally – typically when inbound traffic is 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. It 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

37 “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.”
that are merging to an intermediate point, so as to accommodate another flow that will be merged later, resulting in a more accurate metering constraint.

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.

In Figure 52 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 (KPAs) are used in the context of this document with a more general meaning than their ICAO 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.

RNAV, P-RNAV, RNP, PBN
Area Navigation (RNAV) is “a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained
aids, or a combination of these” (Ref [3]). A further development of the concept of area navigation within the European region, Precision Area Navigation (P-RNAV) is being implemented in terminal airspace as an interim step to obtain increased operating capacity together with environmental benefits arising from route flexibility. No ECAC-wide mandate for the carriage of P-RNAV is foreseen; however European States will progressively introduce P-RNAV requirements for Terminal Area RNAV procedures, as defined in already published AIPs.

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).

Note: recently, the Performance Based Navigation concept (PBN) was 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 (Final Draft)' (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’.

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.

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.

Continuous Descent Approach (CDA), Basic CDA, Advanced CDA
(from Ref [13]):
“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’.”

Basic CDA procedures involve adequate ‘distance to go’ (DTG) information to be passed by ATC on a tactical basis to the pilots so that they can manage their vertical profile.

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 density traffic situations.
15.2 Acronyms

A/C, a/c Aircraft
ACAS Airborne Collision Avoidance System
ACC Area Control Centre
A-CDA Advanced Continuous Descent Approach
AIP Aeronautical Information Publication
AMAN Arrival Manager
ANSP Air Navigation Service Provider
APP Approach Centre / Control
ARWP Agency Research Work Plan
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)
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
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
MONA Monitoring Aids
MTV Mid-Term Validation
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
PF Pilot Flying
PLC Planning Controller
PNF Pilot Not Flying
P-RNAV Precision Area Navigation
RA Resolution Advisory
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBT</td>
<td>Reference Business Trajectory</td>
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<tr>
<td>RNAV</td>
<td>Area Navigation</td>
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<td>RNP</td>
<td>Required Navigation Performance</td>
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<tr>
<td>R/T</td>
<td>Radio Telephony</td>
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<tr>
<td>RWY</td>
<td>Runway</td>
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<tr>
<td>S.Leg</td>
<td>Sequencing Leg</td>
</tr>
<tr>
<td>SESAR</td>
<td>Single European Sky ATM Research</td>
</tr>
<tr>
<td>SEQ</td>
<td>Sequence Manager</td>
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<tr>
<td>SID</td>
<td>Standard Instrument Departure</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard Arrival Route</td>
</tr>
<tr>
<td>TCAS</td>
<td>Traffic Collision Avoidance System</td>
</tr>
<tr>
<td>TMA</td>
<td>Terminal Manoeuvring Area, or Terminal Control Area</td>
</tr>
<tr>
<td>TOD</td>
<td>Top Of Descent</td>
</tr>
<tr>
<td>TP</td>
<td>Trajectory Prediction</td>
</tr>
<tr>
<td>TSA</td>
<td>Temporary Segregated Area</td>
</tr>
<tr>
<td>TTA</td>
<td>Target Time of Arrival</td>
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<td>TWR</td>
<td>Tower</td>
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<td>VNAV</td>
<td>Vertical Navigation</td>
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<td>WP</td>
<td>Work Package</td>
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<td>WTC</td>
<td>Wake Turbulence Category</td>
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</table>
15.3 Reference documents

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Version 1.0
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- End of Document -