APPENDIX A: CCO / CDO FACILITATION AND EXECUTION – LIST OF IDENTIFIED CONTRIBUTORY FACTORS WHICH HAVE AN IMPACT ON OPTIMISED VERTICAL PROFILES

CCO and CDO are natural flying techniques, taught at the beginning of flying training. Flying a continuous climb or a continuous descent is, by essence, quite simple but becomes more complex in a constrained operational world. ICAO Doc 9931 describes CDO as:

“An operation, enabled by airspace design, procedure design and ATC facilitation, in which an arrival aircraft descends continually, to the greatest extent possible, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix / final approach point”.

Doc 9931 goes on to say that:

“The generic term “Continuous Descent Operations” (CDO), has been adopted to embrace the different techniques being applied to maximise operational efficiency while still addressing local airspace requirements and constraints. These operations have been variously known as Continuous Descent Arrivals, Optimised Descent Profiles, Tailored Arrivals, 3D Path Arrival Management and Continuous Descent Approaches”.

These facts summarise the complexity around CCO and CDO. The overall objective is to maximise efficiency in a world of multiple constraints.

To optimise vertical flight efficiency, the basic objective is for ATC to facilitate, to the extent possible, the possibility of the Flight Crew to follow an optimum descent profile. This can be achieved by minimising the number of vertical constraints. When vertical constraints are necessary, they should be set so as to minimise the deviation of the aircraft from an optimal descent profile.

Vertical constraints may result in a level flight segment at an intermediate level below the cruising level. Time spent in level flight at lower inefficient intermediate levels results in increased fuel burn, as fuel burn is much lower at higher levels. Such vertical constraints therefore result in increased fuel burn, associated CO2 emissions and airline costs.

The European CCO / CDO Task Force has identified the major contributory factors (see Table 9) to CCO / CDO execution that could have an impact on vertical efficiency in the climb and / or descent phases. The sub-sections in Appendix A provide a high-level description of each identified factor and its impact on CCO / CDO performance. Examples of case studies that demonstrate good practices to mitigate the impact of each factor can be found in later appendices.

It should be emphasised that these factors are often interdependent. For instance, most of the rationale behind LoA constraints aims at increasing overall capacity by enforcing profiles that take aircraft out of congested sectors.
Factors with an impact on CCO / CDO facilitation and execution

<table>
<thead>
<tr>
<th>Aircraft FMS capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airline Policy / Crew training</td>
</tr>
<tr>
<td>ATCO training</td>
</tr>
<tr>
<td>ATC Workload, predictability and DTG Information</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
<tr>
<td>Sequencing/Throughput/Holding</td>
</tr>
<tr>
<td>Letters of Agreement</td>
</tr>
<tr>
<td>Airspace Design</td>
</tr>
<tr>
<td>Procedure Design</td>
</tr>
<tr>
<td>Parallel Runway Procedures</td>
</tr>
<tr>
<td>Climb vs. Descent Optimisation</td>
</tr>
<tr>
<td>Military Airspace</td>
</tr>
<tr>
<td>Geographical Constraints</td>
</tr>
<tr>
<td>Safety</td>
</tr>
<tr>
<td>Weather</td>
</tr>
<tr>
<td>Human Factors</td>
</tr>
</tbody>
</table>

Table 9: List of contributory factors that have an impact upon the vertical efficiency in the climb and descent phases

A.1 Aircraft Flight Management System (FMS) capabilities

According to ICAO Document 9931, “Continuous Descent Operations Manual”, CDO is defined as:

“An aircraft operating technique aided by appropriate airspace and procedure design and appropriate ATC clearances enabling the execution of a flight profile optimised to the operating capability of the aircraft, with low engine thrust settings and, where possible, a low drag configuration, thereby reducing fuel burn and emissions during descent. The optimum vertical profile takes the form of a continuously descending path, with a minimum of level flight segments only as needed to decelerate and configure the aircraft or to establish on a landing guidance system (e.g. an Instrument Landing System or ILS).”

As CDO is defined as an aircraft operating technique, it is important to understand that the behaviour of each aircraft is complex and may differ from another. The different variables affecting an aircraft’s behaviour and its associated trajectory are extensive. Some of the main factors include aircraft aerodynamic characteristics, aircraft mass, airborne avionics, including FMS capability, airline culture and airline cost indices (i.e. affecting the speed of the aircraft). The latter can result in differing performances between two aircraft of the same type, from the same airline operating to the same airport, if there are operational reasons for the airline to fly one aircraft much faster than the other.
Modern aircraft are equipped with a FMS, which supports the Flight Crews with multiple functions on the journey from the departure airport to the destination airport. These functions include:

- Lateral and vertical navigation by the on-board Area Navigation (RNAV) system, which is an integrated function of the FMS;
- Predictions of time, speed, vertical profiles and optimum altitudes;
- Inputs to the Autopilot systems;
- For modern FMSs with Vertical Navigation (VNAV) system - vertical path guidance;
- For FMSs with basic Required Time of Arrival (RTA) function, speed management to adhere to a time constraint within +/- 30 seconds\(^{14}\); and,
- For latest generation i4D FMSs, RTA function in the descent phase to meet a time constraint with greater precision +/- 10 seconds\(^{15}\).

For each flight, the FMS calculates an optimum climb and descent profile optimised against the business needs of the Aircraft User (AU) for that flight. However, aircraft may not always be able to follow the FMS plan, because the Flight Crew may be given alternative instructions by ATC who need to ensure that separation is maintained at all times. Separation may be achieved through strategic constraints published as part of the Standard Instrument Departure (SID) or Standard Arrival (STAR) routes that aim at ensuring separation between traffic flows, or through ATC tactical instructions. In addition, SIDs and STARs may have vertical constraints aimed at ensuring clearance above high terrain or at reducing noise impact over populated areas. Both tactical and published constraints may limit the freedom for aircraft to fly their optimum FMS-calculated flight profile.

The FMS-calculated climb and descent profile is typically a continuous profile. For descent profiles, legacy FMS are typically programmed to decelerate along non-sloped / level flight segments while state-of-the-art FMS use sloped deceleration segments for speed adjustments. Disruptions due to ATC's strategic or tactical constraints may happen when the flight is required to level-off at some point, thereby interrupting the continuous climb or descent, but also just by restricting the rate of climb or descent, so that the flight is allowed to climb or descend continuously, but at a non-optimum rate.

An optimum descent should start from the Top of Descent (ToD) and be flown in idle thrust. Historically, Flight Crews have used, and still use rules of thumb – based on a 3-degree descent path - (depending on airborne capabilities) to determine their ToD, i.e. when the descent phase will start. These rules of thumb are typically based on the difference between an aircraft’s cruise altitude and the airport altitude, in combination with the remaining distance to be flown (see Figure 4).

However, it is acknowledged that although an average idle descent profile is approximately three degrees, the optimised descent profile of the majority of jet aircraft especially newer aircraft types, may vary between two and four degrees.

---

14 - The basic RTA function guarantees adherence to a time constraint with +/- 30 seconds in the 95 percentile.
15 - The i4D FMS guarantees adherence to a time constraint with +/- 10 seconds in the 95 percentile.
The objective of CCO / CDO procedures is that the aircraft flies a profile that is as close as possible to the optimum profile. This is greatly facilitated by an FMS with VNAV capabilities; for aircraft without VNAV capabilities, Flight Crews must be trained to calculate the optimum ToD and descent speed and/or rate settings in real time for their particular aircraft type, e.g. though rules of thumb developed specifically for their aircraft.

It needs to be stressed that an FMS with VNAV capabilities is not a pre-requisite for an optimised descent, but it typically offers greater repeatability in trajectories flown compared to operations based on Flight Crew judgement and rules of thumb alone. In addition, it should be recognised that crew training on how to calculate the position of the optimum ToD accurately, together with optimum flying techniques, are important for achieving good CDO performance during the descent.

The FMS computes the ToD based on the intended route to be flown and the speed strategy. The speed is either a function of a manually inserted descent speed or the one determined by the Cost Index, representing the ratio of time cost vs. fuel costs for the airline. This is illustrated in Figure 5.

A CI of zero indicates the lowest fuel cost with a subsequent lower descent speed and shallower descent angle. Consequently, the higher the cost index, the higher the descent speed, creating a steeper path, decreasing the distance from ToD to threshold and the time needed for the descent. When the speed is manually set below the CI zero speed (which is the maximum range speed), the descent will be even shallower; the fuel-per-minute rate will decrease, but the overall trip fuel will increase due to the increase in the trip duration. Speeds below the maximum range speed are the most efficient way for absorbing delay in flight.

From ATC’s point of view, using CI to calculate the optimal speed for the descent path to be flown creates a flow of traffic with different vertical profiles, even though they might be the same type of aircraft - which in high demand periods is not optimal. Therefore, the optimum ToD point for each flight is not known to ATC. Experience can help ATCOs predict where the optimal ToD points may be for different airlines / business aircraft types, but it is not an exact science.

The FMS uses the calculated optimum descent path and compares it with the data in the Navigation Database. When the crew inserts the cleared or expected STAR and approach, the FMS combines this descent path with the STAR and the Instrument Approach Procedure, taking any altitude and speed restrictions into consideration, and computes a ToD position.
With Closed Path procedures (see Appendix F), the FMS has information about the DTG, as the whole lateral procedure is defined. When the STAR includes an Open Path procedure, the FMS assumes the distance flown is the shortest distance from the last point of the STAR procedure to the next point in the Instrument Approach Procedure.

In these cases, pilot actions, techniques and experience are essential in managing the vertical profile. If ATC interventions result in extended horizontal profiles, they may create an inefficient level segment and so increase fuel burn and noise. ATC should provide DTG as soon as possible so that the crew is able to calculate the most efficient profile, taking the Open Path segment into account.

Any lateral, vertical or speed change after the descent has been initiated will make the aircraft deviate from its computed optimal descent path. Shortcuts, speed constraints (to reduce speed or rate of descent below the originally planned descent speed), higher tailwinds or unanticipated intermediate altitude restrictions (level-offs), will leave the aircraft in a high-energy situation. In contrast, extending the distance to be flown, constraints to increase speed or rate of descent or higher headwinds will create a need to use extra thrust at non-optimal altitudes and may also result in inefficient intermediate level segments - or even more inefficient low-rate descents. In both cases, the Flight Crew should strive to optimise the descent within the constraints and return back as efficiently as possible to the unconstrained path.

An exception to the support provided to the Flight Crew by the FMS in the management of the descent when there are no unforeseen constraints relates to the deceleration segment. In the standard functioning of a Boeing aircraft, the FMS carries out the deceleration seamlessly during the descent phase. In contrast, the standard functioning of the FMS in an Airbus aircraft creates a level segment prior to the final approach segment to allow for deceleration. In newer Airbus aircraft e.g. the A350, with the Honeywell FMS, there is a new CDO feature (see Figure 6) that allows the deceleration to take place in a descending segment. For other Airbus family members e.g. the A330 or A320 neo, this functionality is proposed only as a chargeable option. Where the FMS does not support deceleration in the descent phase, Flight Crews should be trained in pilot techniques to avoid the level segment or at least limit it to no more than 20 seconds' duration.

FMS issues may hinder the Flight Crew’s ability to comply with constraints along the descent. For example, the SESAR ODP[16] (Optimised Descent Profiles) demonstration documented that some FMSs may, under certain circumstances, delete vertical constraints along a STAR, which the FMS logic considers unnecessary.

---

For example, when a constraint was above the cruising level, it was deleted, and with it any additional constraints over the same waypoint (in the case of altitude windows) were also deleted. This resulted in a low level of compliance with the vertical constraints, which rendered them useless for separation purposes. Subsequent activities reported by the Task Force members have shown how an adequate information campaign can dramatically improve the rate of compliance with vertical constraints.

The ICAO CCO / CDO procedures are based on the strategic analysis of the fleet composition and traffic flows in order to establish climb and descent paths that achieve a certain degree of segregation of traffic flows. This results in standard climb and descent profiles which introduce constraints that are the least penalising considering the fleet composition. When aircraft fly these SIDs and STARs, the need for ATC to introduce new constraints in the tactical phase is minimised, thanks to the strategic segregation of traffic flows.

Even though the Flight Crew is ultimately responsible for the management of the flight path, including compliance with all ATC constraints and regardless of the level of support provided by their FMS software, it is important to acknowledge that they can be hindered by the limitations of their FMS. It is essential that Flight Crews are trained to understand the limitations of their FMS, and to actively manage the flight path to ensure that all published constraints are complied with.

### A.2 Airline Policy / Flight Crew training

CCO and CDO operations are strongly promoted by some airlines but not others. By promoting CCO and CDO, airlines may not only meet their own internal policies or SOPs (Standard Operating Practices) on CDO but also comply with airspace and airport regulations on CDO which enable performance improvements and result in fuel and emissions savings.

For airlines to successfully enhance the efficiency of the vertical profiles, a combination of theoretical and practical training is required to increase Flight Crew awareness and the proactive management of the flight. Therefore, performance improvements can be facilitated through the development of SOPs and the use of specific training and simulator exercises on managing CDO performance.

From previous analyses undertaken by EUROCONTROL and going by experiences of certain States such as the UK, Belgium, Germany and Sweden, it can be seen that Flight Crew / airline culture can have a sizeable impact on the amount of CDO carried out by different airlines. Large differences in time spent at inefficient intermediate level segments may be explained by individual flights being subject to safety or capacity constraints. However, when the data are aggregated over larger time periods, it is clear to see that between airlines flying the same fleet, and routes, large differences in performance may be found. These differences can be attributed to the airline’s CDO policy (or lack thereof).

In addition, statistical differences in performance between individual pilots belonging to a single airline in the same fleet may indicate issues related to training, or human performance issues, such as those as detailed in Appendix A5.

A survey carried out by the European CCO / CDO Task Force generated > 120 responses, from ~60 airlines and yielded surprising results. The results showed that some (mainly low cost) airlines are leading the way by including CDO and descent optimisation content in their initial training, conversion training and refresher training. They are also maintaining CDO SOPs; producing airport-specific CDO good practice guidance material; and measuring CDO performance with related performance feedback to Flight Crews - all of which the CDO Task Force considers as good practices.

**The vast majority of airlines, however, do not do this.** It appears that while the Task Force may engage with individual CDO-focused airline representatives, the overall airline culture appears not to be set up to support enhanced CDO operations, and so they may miss out on the benefits from these operations. In particular, these results were found:

- Only 33% of airlines surveyed had a Standard Operating Practice on CDO;
- Only 39% of airlines surveyed provide Flight Crew with guidance material / good practices on performing CDO for approaches to specific airports;
53% of airlines have CDO content detailed in their refresher training but this falls to 45% for ab-initio training and 18% for aircraft base training;

- Fewer than 25% of airlines measure CDO performance per flight, and only 16% measure CDO performance by individual pilot; and,

- With the benefit pool available from optimising fuel burn in the descent phase, it is surprising that only 38% of airlines surveyed undertake benchmarking analyses of the amount of fuel used in the descent phase.

### A.3 ATC Training

Non-uniform behaviour between aircraft and the lack of information sharing between air and ground actors about the intended aircraft profile, especially in the descent phase, make it challenging for ATC to help each aircraft fly its optimum profile.

The function of an ANSP and its ATCOs is the safe, orderly and expeditious flow of air traffic. While safety should never be compromised, ATC plays a key role in supporting and facilitating CCOs and CDOs by minimising constraints. This should include the removal of strategic ATC constraints (e.g. in published SIDs and STARs and in LoAs) whenever they are not necessary, and also increasing the predictability of the flight path for Flight Crews by informing them of the intended 3D trajectory and potential speed constraints. CCO / CDO facilitation needs to be a clearly identified objective, fully supported by ATC Operational Management.

While calculating and executing the optimum climb and descent profile within existing constraints is the responsibility of the Flight Crew, its execution needs timely and appropriate ATC clearances. ATCO training should cover the impact that different conflict resolution strategies have on fuel consumption and noise. In addition, training should draw attention to airspace limitations and traffic complexity, highlighting the complex interdependencies between optimising the different KPAs, such as capacity, efficiency and the environment.

In Europe, the responsibility for ATCO training lies with individual ANSPs, based on the Common Core Content (CCC) training material and the guidelines maintained by EASA. The ATCO CCC consists of a set of subject objectives and training objectives together with mandatory / optional content.

The European CCO / CDO Task Force has proposed specific updates to the training objectives for Area and Approach ATCOs to ensure that more content is added to the training objectives relating to CCO / CDO and the optimisation of the vertical profiles. These updates include specific objectives on aircraft energy management principles and the proposal that objectives should not only be included as part of the theoretical training, but also that specific CDO and CCO objectives should be added to practical simulation exercises developed for ab-initio and unit-endorsement training.

In addition, the Task Force has developed a refresher training for ANSPs on aircraft energy management for ATCOs, which can be found on the Task Force webpages on the EUROCONTROL website. More details about this material can be found in Appendix I.

### A.4 ATC Workload, predictability and DTG information

Predictability in the trajectory to be flown is of paramount importance, as it allows the Flight Crew to optimise the descent profile. As stated above, this is ideally achieved through the highest repeatability of the trajectories flown and by flying a Closed Path procedure, which takes the aircraft in a continuum from the en-route phase until landing. This allows the FMS or the Flight Crew to plan and manage the most efficient descent profile. However, in some complex and/or congested airspace, published procedures may not be flown in peak periods and tactical interventions (e.g. ‘vectoring’ or ‘holding’) will be necessary.

17- Some airports do report CDO performance and report the performance back to airlines (See Appendix Q)
19- https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations
To support the management of the vertical profile and increase predictability for the Flight Crews, whenever the track to be flown differs from, for example, a published STAR, the ATCO should give the Flight Crew a precise descent clearance including the number of track miles (DTG). This should be given as soon as possible so as to allow the Flight Crew to fly an optimised descent profile. From the Flight Crew perspective, this should ideally be received as early as possible during the descent (ideally even before the descent starts, in order to enable a modification of the ToD, where required) and updated by the Controller during the descent if there are any changes. A general rule of thumb would suggest that an update to DTG should be provided if any tactical interventions lead to trajectory changes for the aircraft that would result in a DTG that changes by more than 2-3nm.

However, it is acknowledged that the provision of DTG with high granularity is not always an easy task for the ATCO; it adds to ATCO workload, especially in more complex and dense airspace, and will only be provided on a best-effort (i.e. workload permitting) basis. This is especially true if the ATCO does not have an appropriate system support tool which can easily calculate and provide the DTG. It is important to highlight that for the Flight Crews to be able to use DTG information for descent optimisation purposes, they will also need to have a predictable speed profile. Any anticipated speed constraints by ATC should be passed on to the crew as soon as possible.

The impact of the unpredictability of the flight path is illustrated below by the Brussels airport case.

At Brussels Airport (EBBR), when Runway 01 (RWY01) is used for landing, depending on the traffic intensity, the vectoring strategy by ATC can be quite different, having an overall impact on distance flown and the resulting CDO performance. As illustrated in ???, the number of track miles can vary from 30nm to almost 80nm in extreme cases, from an altitude of approximately 8,000-9,000 ft. This variability makes it very challenging for Flight Crews to fly an optimised descent profile.

If the Flight Crew were to assume that a long path would be flown, if allowed by ATC, they would try to stay high and even level-off, in order to save fuel. However, should ATC finally clear the aircraft for a shorter path, the aircraft would find itself in a high-energy configuration that would be difficult to manage. The aircraft would have to maintain high speed in order to quickly lose the extra energy, making it harder for the aircraft to fly a safe stabilised approach, and Flight Crews may even have to add drag by using speed brakes, which would offset the potential fuel benefits of having stayed higher earlier. Unsurprisingly, when Flight Crews do not receive DTG information, they will typically plan their descent assuming that the flight path will be the shortest one, so that they are ready to turn inbound and fly a safe stabilised approach regardless of when they receive an ATC clearance. If in the end they are required to fly a path extension, they will inevitably find themselves flying a long inefficient intermediate level segment using unnecessary thrust.

This clearly highlights the need for ATC to communicate the DTG by ATC. Prolonged level flight at low altitude should be avoided to the greatest extent possible. On the other hand, providing regular updates of DTG increases the workload of the ATCO, especially when traffic levels are high.

Figure 7: Unpredictability of the vectoring at RWY01 at EBBR (Source: Brussels Airlines)
The predictability of flight paths can also be increased by using Area Navigation (RNAV) or Required Navigation Performance (RNP) route structures such as Point Merge, merge-to-point and trombone structures. These structures are described in detail in Appendices A7 and F. The predictability of the flight path in these structures in the last part of the approach is very good, but is often achieved at the expense of introducing restrictions and unpredictability earlier in the descent.

For example, in a Point Merge system, all aircraft are required to level-off by design when entering the lateral holding leg (in the case of parallel overlapping legs), and, in a Merge-to-Point system, all aircraft are subject to the unpredictability of vectoring until they are cleared to proceed direct to the merge point. In a trombone, Controllers use the trombone structure for path extension rather than vectoring, but they are expected to shorten the flight path when a path extension is not necessary, thereby introducing uncertainty of DTG for the Flight Crew. In dense TMAs, such structures aim at providing a trade-off between flight efficiency and capacity, recognising that the ideal CDO may not be available at all times in dense terminal areas. What is limiting the CDO application is not the structure per se but the traffic demand.

At some airports, a systemised predictable approach supported by well-publicised and accurate DTG values and standardised approach speeds and levels may provide very high levels of predictability. This is the case at London Heathrow (EGLL). At Heathrow, traditional racetrack holding patterns are routinely used, but after aircraft leave the holding pattern, DTG is provided and the operation follows a very predictable procedure in terms of speed, allowing for very efficient descent planning in the last part of the approach. Such efficient descent planning will only work when all arrivals fly standardised speeds and levels. However, in such cases, the primary consideration may be runway throughput so whilst predictability may be enhanced at lower levels, the result is that the inefficiency may be moved elsewhere, to extensive level flight at higher levels, or in the form of holding.

The optimisation of the last part of the descent was the focus of the previous CDA Action Plan, and in the Single European Sky Third Reference Period (RP3) this will be monitored at the local level. However, this Action Plan aims at building on that initiative by promoting a holistic view of the optimisation of the descent, so that on top of the noise impact at lower levels, the impact on fuel burn / CO2 emissions of the whole descent is considered.

While only the last part of the approach is of interest for noise mitigation, the situation is very different for fuel: the overall fuel burn is what is relevant: savings in the lower portion of the approach are meaningless if they come at the price of higher fuel burn earlier in the descent.

To overcome the extra workload related to DTG, some ANSPs like ANA-Lux, ENAV, HungaroControl or Bulatsa have developed solutions that suppress the need to deliver DTG information or they provide a tool that makes the calculation for the ATCO (see Appendix H for more information).
A.5 Human Factors

When trying to find performance improvement for the efficiency of the climb and descent phases of flight or implementing CCO / CDO to / from higher levels, it is important to understand the human element. The definition of CDO states that it is an aircraft operating technique, facilitated by ATC and so may be affected not only by the network and local situation, traffic complexity or the availability of new tools, but also by the human being.

Numerous studies have shown that the mentality of individual ATCOs or Flight Crew members may contribute to the amount of CCO / CDO actually flown. For example, in the initial stages of the HTO Study (see Appendix Q), CDO levels were found to be low as ATCOs had little faith in and understanding of both the procedure and the Flight Crews’ ability to comply with the altitude restrictions of the procedure. This made ATCOs reluctant to offer optimised descents.

There are two important steps to follow in these cases:

- **Situational awareness**: most operational staff are aware of aviation’s environmental impacts. Focus should be on working on how the communication of small changes, with little or no effect on workload, can significantly increase efficiency; and,
- **Training**: courses focused on lecturing and the reading of prescribed materials may not be the right approach. Specific training with clear practical examples is a better training mechanism than relying solely on theory. In addition, a visible focus on training from management demonstrates high-level commitment to those who need to change their attitude.

With these two steps, engagement can be expected from staff, as they are now convinced, instead of forced, to apply more efficient procedures.

The Hawthorne Effect is a phenomenon where the subjects of a study have been shown to alter their behaviour due to their awareness of being observed. While this may invalidate the significance of a study based on the analysis of a sample of the data, due to the lack of representativeness of the modified behaviour, the effect can also be used actively to increase operational performance. This requires very large data samples, which should where possible, comprise the whole population. This will lead to a modification in behaviour: the “being observed” effect results in a systematic improvement of operational performance.

In the UK, NATS found that publishing CDO statistics at the airports they control, broken down to the ATC watch level and time of day, improved the rate of CDO adoption over time. Many airlines, particularly from the low-cost segment, have shared similar experiences in monitoring individual performance with the Task Force.

While the Task Force wants to promote a culture in which safety is the primary consideration, the Task Force’s assessment is that this can be made compatible with a blame-free operational performance monitoring programme for individual Flight Crews and ATCOs.

However, it is also important to mitigate the potential impact of the Goodhart law, which states that when an indicator becomes a target, it may cease to become a good indicator. In the CCO / CDO domain, this may be an unintended effect of using binary indicators (i.e. is a CDO performed: yes / no - as per RP3). For example, Pilots and especially Controllers would be encouraged to perceive that, once a flight has levelled-off once during the climb or descent, the flight would already be classed as a non-CCO / CDO flight by the metric. Therefore, their reaction could lead to their no longer being too concerned about further optimising the flight. This could lead to a system in which a few aircraft are heavily penalised, but allowing most flights to have a climb / descent with no level-off, so obtaining a better overall indicator.

The harmonised indicator proposed by the Task Force measures the time in level flight instead of just whether there was or not a level segment, thereby solving this issue. This new indicator is more refined than the RP3 indicator, and is the best available today; however, as described in Appendix B, it has its own limitations. As per the Goodhart law, a different type of sub-optimal behaviour may be encouraged: controllers may impose heavily penalising speed or vertical rate restrictions.
in order to avoid or to shorten a level-off, and in this case the inefficiency would not be captured by the metric. CCO / CDO training material for Controllers should include information to raise awareness on this topic and provide guidance on the trade-offs associated to each different kind of clearance. Appendix H contains detailed information on the Task Force’s findings in the area of trade-offs.

A.6 Capacity (Network level)

A significant part of the fuel consumption for a longer flight is typically used in the cruise phase. Restrictions on the cruise phase of flight are the most important phase in terms of fuel efficiency. Restrictions to the final cruising altitude can be imposed in the planning phase (due to Route Availability Document (RAD) constraints, tactical Air Traffic Flow Management (ATFM) measures (STAMs)); they can also be imposed tactically by ATC during the flight. Whether tactical or strategic, restrictions to the cruising altitude will typically have a larger impact on the overall fuel burn than vertical restrictions during the climb and descent phases.

This Action Plan’s scope is limited to the climb and descent phases of flight, so the cruise phase is explicitly out of scope. Nevertheless, the Task Force would like to highlight the fact that avoiding restrictions on the final cruising level should in general have priority over the climb and the descent.

One must avoid the false perception that it would be appropriate to restrict the final cruising level in order to carry out CDO or CCO. This could happen, for example, if once a level-off below (but close to) the final cruising level in the climb is required by ATC, Controllers were to assume that “it would not be worthwhile to clear the aircraft for further climb”. In such a situation, if further climb is possible, ATC should always give the Flight Crew the choice to continue climbing to the higher cruising level that had originally been requested. The Flight Crew are the only competent party to make an assessment of whether it is more efficient to continue to climb or not.

In an optimum airspace configuration, CDO should be facilitated from the top of descent point to the final approach phase. However, there is a balance to be struck between capacity and efficiency, and this can be due to state boundaries, sector boundaries or local working agreements for the transfer of traffic in a systemised air traffic network.

Each situation can be different, and in circumstances where systemisation is being utilised, the priority for capacity may outweigh the necessity for airspace efficiency. An example of this would be the boundary between Irish and UK airspace, on an eastbound flow from the Northern Atlantic, where London TMA inbounds are forced down to a lower level to permit UK overflights to climb. This optimises the cruise for one set of flights, but introduces disadvantages for the other flow, but this is used for capacity and sequencing reasons. In situations where restrictions do not need to be enforced, there are options available for Controllers to relax systemisation to facilitate a better cruise to descent profile for the aircraft type and operating technique. Such examples may be found all across Europe, and while situations are not identical there are mitigation synergies that European ANSPs can share.
In congested European airspace, capacity is often a limiting factor. To deal with capacity issues, some initiatives were recently taken on a Network Level, such as the 4ACCs (4 Area Control Centre) initiative in 2018.

The 4ACCs initiative was launched in Spring 2018, in coordination with the Network Manager and four European ACCs (London, Reims, Maastricht Upper Area Control Centre (UAC) and Karlsruhe UAC). Its aim was to minimise system-wide en-route ATFM delay, through the implementation of measures such as cross-border level capping at RAD level and re-routing.

In the area of vertical flight efficiency, the initiative resulted in more than doubling the number of city pairs with RAD restrictions to the cruising level, compared to 2017. The initiative was expanded in 2019 (as the eNM (Network Manager) Summer measures) to cover more ACCs and city pairs. For illustration purposes, the top 20 airport pairs with the highest amount of total vertical flight inefficiency in the flight planning during AIRAC cycle 1907 (June-July 2019) are shown in Figure 8.

The flight levels next to the arrows connecting departure and arrival airports indicate the altitudes of the RAD constraints on these airport pairs. Flights between seventeen out of the twenty airport pairs were constrained to keep them either completely or partially below the ACCs involved in the 4ACCs Initiative. Restricting the cruising altitude for flights between these city pairs freed up capacity in the higher airspace. This is an example of the trade-off between flight efficiency and capacity, which highlights the need to take into account all aspects of performance.

These level capping constraints are further complicated by the varying performance envelopes of different aircraft types. For example, business aviation aircraft have traditionally been at the forefront of enhanced new capabilities such as winglets, advanced avionics etc. In addition, business jets usually fly faster and higher than commercial aircraft and are able to achieve and maintain initial climb rates far in excess of Airbus and Boeing aircraft across the range of normal operating weights. In addition, they usually start descent at a later point than other aircraft as most business jets have a lower Lift / Drag ratio and lower flight idle thrust compared to commercial jets.
One of the main specificities of business aviation is to be able to capture FL410 as an initial flight level, which means that business jets are flying in cruise above commercial traffic and are therefore not contributing to the increased demand for cruise airspace. As business jets often fly at and above these higher levels, they may be more penalised by network capacity measures than commercial jets. In accordance with a ‘most capable, best served’ policy there could be the possibility of using the high performance climb rates of business jets to allow them to climb rapidly above the congested flight levels to enable more optimum vertical profiles. As an example, a typical business aviation aircraft will burn approximately 25% more fuel when cruising at FL330 compared to cruising at FL450 for a given distance.

Level capping and the objective to systemise traffic flows in areas where flows needs to be regulated (to cope with capacity shortfalls, reduce network delay or reduce the possibilities for sector overload) do not have a direct impact upon the possibility to fly CCO / CDO or optimised descent profiles.

However, there may be indirect impacts upon CCO / CDO. For example, CCO / CDO performance (in terms of the average time in level flight) may actually be enhanced because time in level flight can be reduced, as the flight never reaches the more efficient altitudes where interactions with other aircraft may be expected in the descent phase (resulting in level flight). This will give a false performance result as, overall; the level capping means that the flight spends longer cruising at more inefficient lower cruising levels.

Furthermore, whereas stakeholders may have previously worked hard to develop new procedures or create new coordination points between sectors to enable a more efficient and higher handover of traffic between sectors (thereby resulting in lower fuel burn and emissions); these may be cancelled out by the eNM measures.

For example, at LOWW (Vienna Airport), the ODP Project previously created a change in altitude restriction points at NIMDU on the NEMAL1W STAR, resulting in the median altitude of arrivals over NIMDU being on average 3,000ft higher than before. Because of the eNM measures the transfer of control conditions from Karlsruhe and then through the Austrian sectors changed, rendering the favourable altitude restriction overhead NIMDU obsolete. As a result, CDO from more optimum levels was no longer possible while the eNM measures were in place and was subsequently not again addressed once those measures were no longer applied.

By capping the cruising levels of flights between city pairs, the inability of flights to cruise at the more fuel-efficient higher flight levels will increase the total vertical flight inefficiency of the en-route phase and restrict the benefits that could be available from an optimised descent from ToD on a more optimal (higher) profile.
A.7 Capacity at the local level – Sequencing / Runway throughput and holding

For an airport to operate at top capacity, it is necessary to maintain runway throughput in order to ensure that there will be no gaps in the sequence, for that would waste capacity. ATCOs use a combination of techniques - known collectively as arrival management techniques - in order to organise and sequence aircraft for landing with the adequate separation between them to maintain the required runway throughput. Arrival management techniques include early traffic synchronisation techniques to smooth the delivery of traffic from the en-route sectors into the TMA, and path extension, vectoring and speed control for sequencing and merging traffic in the TMA.

Sequencing and merging is fundamentally a tactical activity, where ATCOs react dynamically to the evolution of traffic in order to safely organise aircraft in sequence for landing. The traditional way of ensuring that runway throughput is maintained is to use racetrack holding patterns near the airport.

WHY IS HOLDING NECESSARY?

Figure 9: Visualisation of traffic in London TMA, including its racetrack holding patterns.

Capacity at the local (airport) level may negatively impact the efficiency of the vertical profile performance. The London Heathrow (EGLL) case is a good illustration. Heathrow has a landing rate of 40+ arrivals per hour for 16 hours a day with an average holding time of circa three minutes per aircraft. The three minutes holding time per aircraft could be eradicated but comes at the cost of only 30 arrivals per hour. Airlines and the airport ‘accept’ this arrival delay to maximise the runway throughput.
Aircraft fuel efficiency is highly dependent on altitude, and higher holding altitudes consume less fuel. From a noise perspective, it should be noted that higher holding altitudes are preferable as well. To enable the optimisation of the descent after leaving a holding pattern, which is typically followed by vectoring, accurate up-to-date DTG information is essential.

A side effect of traditional racetrack holding patterns is that all arrivals in a holding pattern have no lateral separation, and therefore need to be separated vertically by ATC through tactical clearances. Typically, aircraft will be cleared for descent 1,000ft at a time, with each aircraft in the holding pattern being cleared to descend when the aircraft holding below has vacated the corresponding level.

**A.8 Letters of Agreement / RAD Restrictions**

The purpose of a LoA and RAD vertical restriction is to define the coordination procedures to be applied between Air Traffic Service (ATS) units when providing ATS to General Air Traffic Instrument Flight Rules / Visual Flight Rules (IFR / VFR) and / or Operational Air Traffic. They underpin the management of high traffic demand in the European Airspace by providing strategic separation of traffic flows; but they can often be based upon conservative performance data or traffic flows.

As is the case with any restriction, it is essential to ensure that **LoAs should be applied only when they are actually needed and that the constraints they impose are as least restricting as possible.** Some LoAs may have been published several years ago without any subsequent revision and therefore may not reflect more modern fleet mixes or may not be applicable in low traffic conditions.

Via ATCO tactical clearances, some flexibility can be given in terms of the altitude of the transfer of control but this may have a negative impact on predictability, in particular on downstream sectors. When level restrictions due to inefficient LoAs are sub-optimal, this will have an impact upon flight planning by CFSPs and therefore the subsequent fuel planning and associated fuel consumption will also be impacted.

**THE IMPACT OF LoAs AND RAD RESTRICTIONS**

Figure 10 illustrates how an arrival flight may be forced down to an inefficient flight level to comply with individual LoAs between ATC Centres or sectors. These LoAs follow the agreement of specific coordination levels between ATC sectors or Centres to help reduce sector overloading or sector complexity, or to strategically separate traffic flows, e.g. by avoiding crossing traffic in higher sectors. However, as can be seen from the following example into Brussels, this comes at the price of forcing the Flight Crew to start the aircraft’s descent approximately 20 minutes early and fly for a distance of 150nm below its ideal vertical profile as calculated by the FMS. This will have a significant impact upon a flight’s environmental performance. In fact, in this example, while the descent starts at approximately 225nm from EBBR, the actual FMS-calculated ToD point is at 86nm from EBBR.

![Figure 10. An inefficient vertical profile due to LoAs/RAD restrictions into EBBR (Source: TUIfly)](image-url)
The purpose of RAD and LoA restrictions is essentially the same, but RAD restrictions are published in the RAD document and need to be taken into account by AUs for flight planning. In contrast, flight plans do not need to be compliant with LoAs that are not listed in the RAD.

LoA, RAD restrictions and intra-centre coordination conditions between sectors that impose vertical restrictions should whenever possible be compatible with optimum descent profiles. It is also important to increase the granularity of the vertical constraints, so that they are adapted to the needs of each runway configuration, high / low demand periods, seasonal traffic, week / weekend traffic, etc.

In the execution phase, ATCOs should be encouraged to tactically waive penalising vertical restrictions whenever possible, and Controller support tools should facilitate the coordination of constraint waivers between Controllers in the same or in neighbouring Area Control Centres (ACCs).

It is also essential that LoAs and RAD restrictions be reviewed and kept updated. It is therefore imperative that processes are put in place to ensure that LoAs and RAD restrictions are routinely reviewed by ANSPs and NM.

**A.9 Airspace and Procedure Design**

Airspace design is one of the principal contributory factors that may affect the ability of a flight to fly a CCO / CDO and there is no single solution for the optimisation of the vertical profile at all airports. In Europe, general principles and technical specifications for airspace design are laid out in Part 1 of the European Route Network Improvement Plan (ERNIP).

While arrival routes should follow the optimum idle descent path of the most common aircraft profiles for each individual runway, many factors may need to be taken into account when designing arrival routes:

- Aircraft weights;
- Prevalent winds;
- Temperatures;
- Speed schedules; and,
- Optimum descent angles etc.

Rules of thumb, however, are available for supporting descent route creation. In addition, there is a need to be flexible when designing an arrival route - airspace and procedure design usually consider a workable solution for traffic peaks but may hamper optimised profiles during non-peak periods. When such peak / non-peak periods are determinable, solutions may be found to make available optimised descent profiles for specific times / days / seasons or under specified conditions.

The Procedure Designer is responsible for implementing flight procedures based on a concept of operations or CONOPS, and ensuring that they comply with ICAO criteria. The CONOPS could be for arrival or departure routes, transitions, approaches etc. When possible, optimised climb and descent operations are facilitated by either defining “CCO or CDO procedures” or by giving flexibility to Pilots to manage their descent. It can be done, for instance, by imposing only minimum altitudes based on obstacles, airspace, LoA etc.

The Procedure Designer is responsible for implementing the airspace designer’s airspace design concept and ensuring that it complies with ICAO criteria, for instance to maintain obstacle and terrain clearance together with meeting further criteria such as aircraft performance limitations, airspace capacity and air traffic control separation requirements, as well as environmental concerns. Both the Airspace and Procedure Designers are likely to work for, or closely with, the ANSP.

---

Closed and / or Open STARs are a local airspace design decision with their own set of benefits. However, where Open STARs are implemented, optimum profiles and the provision of DTG may still be enabled by the use of supporting tools such as PMS, Arrival Manager (AMAN), Cross-border Arrival Manager (XMAN - provided any speed constraints are given prior ToD.) or the T-bar (a type of approach procedure that supports traffic planning and sequencing).

The ICAO document 8168 Volumes I and II (PANS-OPS) must be the basis for airspace and procedure design:

“Procedure design should consider the environmental and efficiency advantages afforded by implementation of a continuous descent operation (CDO). Airspeed and altitude/level restrictions, if any, should be included. These should take into account the operational capabilities of the aircraft category involved, in consultation with the operators” (ICAO PANS-OPS).

It should also be noted that ICAO PANS-OPS also contains a recommendation for the inclusion of a level-segment in the intermediate approach segment (for safety reasons):

“Because the intermediate approach segment is used to prepare the aircraft speed and configuration for entry into the final approach segment, this segment should be flat or at least have a flat section contained within the segment” (ICAO document 8168, Part I Section 4 Chapter 4 §4.3.3).

The procedure is designed so it will always allow for a level segment if required. Nevertheless, some state-of-the-art FMSs are designed to guide the aircraft along a sloped deceleration segment, allowing the aircraft to configure the aircraft without the use of the level segment. The presence or not of a level segment in the intermediate approach segment is usually affected by the SOPs of the airline as detailed in the Operating Manual (OM), as opposed to the procedure design. This is also recognised in ICAO document 8168, Part I Section 4 Chapter 4 §4.3.3; “to fly an efficient descent profile, the Pilot may elect to configure while in a continuous descent along this segment.”

These documents provide specific guidance for the design of procedures that support optimised climb and descent profiles, including recommendations for balancing CDO in the context of other ATM needs:

- ICAO CDO Manual (ICAO Document 9931)
- ICAO CCO Manual (ICAO Document 9993)
Vertical constraints should whenever possible, be designed so that they do not penalise aircraft flying a continuous descent using a descent rate between 220ft/\text{nm} and 350ft/\text{nm}, which covers the optimum descent rate for most aircraft. Figure 11 illustrates this case.

When the crossing windows cannot be set to allow the full 220-350ft/\text{nm} range of descent rates, simulations should be performed in order to evaluate the different design options against the traffic mix that flies that route, with the objective of identifying new crossing windows that minimise the percentage of aircraft whose FMS-calculated optimum descent profile can’t be executed. The ICAO manual uses an example from Los Angeles International Airport to illustrate this case; in this case, the constraints were set in a way that a continuous descent was possible provided that the range of descent rates be in the interval 252 - 331ft/\text{nm} (instead of the 220 - 350ft/\text{nm} generic recommendation).

The creation of each procedure should be fine-tuned through a consultancy process between the ANSP, the Aircraft Operators and where necessary, the Airport Operators, as an optimised design should take into account both the constraints and requirements of each party.

Closed and / or Open STARs are a local airspace design decision with their own set of benefits. Their design is supported by the ICAO Manual on the use of Performance-Based Navigation in Airspace Design (ICAO document 9992), and by the extensive documentation of the various available options in the solution packs of the corresponding SESAR solutions21. Where Open STARs are implemented, optimum profiles and the provision of DTG may still be enabled by the use of support tools.

A.10 Parallel Runway Operations / Procedures

One of the constraints preventing the flying of optimised CDO until the runway threshold is the use of parallel runway operations. For a dependant runway operation CDO is feasible but independent operations may require high side / low side approaches.

According to ICAO PANS ATM doc 4444, section 6.7.3.2.3, arrival procedures for independent parallel approaches are subject to these conditions:

- **When vectoring to intercept the final approach course or track, the final vector shall meet the following conditions:**
  a) Enable the aircraft to intercept at an angle not greater than 30 degrees;
  b) Provide at least 1.9 km (1.0 nm) straight and level flight prior to the final approach course or track intercept; and
  c) Enable the aircraft to be established on the final approach course or track, in level flight for at least 3.7 km (2.0 nm) prior to intercepting the glide path or vertical path for the selected instrument approach procedure.

These conditions imply that the procedure should be designed with a straight and level segment, although it is not mandatory to actually fly it level.

Vertical flight efficiency during independent parallel runway operations may also be negatively affected for safety reasons. For such approach operations, PANS-ATM section 6.7.3.2.4 states that:

- A minimum of 300 m (1 000ft) vertical separation or, subject to radar system and situation display capabilities, a minimum of 5.6 km (3.0 nm) radar separation shall be provided until aircraft are established:
  a) Inbound on the ILS localizer course and / or MLS final approach track; and
  b) Within the normal operating zone (NOZ).

This implies that when sufficient lateral separation is not available, in order to provide separation between simultaneous arrivals to the parallel runways, arrivals to one runway may expect a level segment until both aircraft are established on the localiser.

---

22 Dependent parallel approaches are an ATC procedure permitting approaches to airports having parallel runways. Separation between aircraft is achieved by “staggering” the aircraft at a specified minimum diagonal distance corresponding to the runway centreline separation. Independent parallel approaches are approaches where radar separation minima between aircraft on the two parallel runways are not prescribed.
INDEPENDENT PARALLEL APPROACHES

At a typical airport where independent parallel approaches are in operation, they could be in use during an afternoon arrival peak (see). In such operations, the operating mode requires that at least 1000ft vertical separation be maintained between the traffic of the parallel runways until the aircraft are established on ILS. In practice, this is achieved by having the lower side traffic flying in level flight at 2000ft before it can turn inbound. At the same time, the arrivals on the higher side need to be at or above 3000ft. Thus, parallel runway operations do not prevent having CDOs on the high side, but level flight before joining the final approach cannot be avoided on the low side.

The SASP Panel (Separation and Airspace Safety Panel) of ICAO may or may not consider amendments to the texts detailed above in the future, but mitigations to the requirement to level-off on one side have already been implemented with a new separation standard approved by the SASP Panel in 2018. This new PBN separation standard called ‘Established on RNP’ or EoR, allows aircraft cleared on RNP-AR approach procedures to safely land simultaneously on parallel runways without the requirement for a separation minimum of 1,000 feet vertically or 3nm laterally. EoR was first established at Calgary Airport, Canada in November 2018.

A.11 Optimisation of the climb profile versus optimisation of the descent profile

There are interactions between arrival and departure flows in the TMA around airports. This is because departures from an airport will fly to destinations that may be located in all geographic extremities whereas arrivals will arrive at an airport from all geographic locations. At some point arrival and departure routes will have to cross one another (see Figure 13).

Where such routes cross, aircraft may be vectored on a heading to avoid a conflict. For arriving traffic, vectoring will mean a deviation from the ‘straight-in’ route, therefore implying an increase in distance flown (with more fuel burned and therefore more CO2 produced).

Alternatively, vertical separation will be provided. Depending on the rates of climb or descent, vertical separation may inev-
Itably involve a period of level flight as the aircraft pass one another and lateral separation is achieved, which will preclude the possibility of one or both aircraft having to maintain a continual climb or descent. Therefore, in busy airspaces where such interactions occur, it may mean that a fully optimised system may not be possible or, if it is, significant airspace changes will be needed.

Interactions between flights lead to the understanding that if vertical separation between aircraft needs to be maintained - therefore creating a level-off for one or both aircraft - it is desirable to find the most efficient possible clearance, in the sense of minimising the fuel penalty.

It might be possible to design the system in a way that both departing and arriving aircraft are optimised, meaning that the routes are designed conflict free so that both departures and arrivals can fly their optimum vertical profile. This should provide optimal benefits for the TMA in terms of reduced fuel burn and CO2 emissions compared to optimising only one phase i.e. the departure or arrival phase.

However, if optimising the vertical profiles of both departures and arrivals results in an increase in the horizontal track flown, the expected gains of eliminating the level-off diminish by the extra distance flown and needs to be carefully analysed. The vital point is to reduce the fuel/Nm in the direction towards destination.

The Task Force notes at an approximate that there is no guidance material addressing the optimisation of arrival and departure flows within the TMA system. Previous CDO guidance material highlighted potential interdependencies but any proposed solutions are not prescriptive.

The 2008 European Flight Efficiency Plan recommended the implementation of ‘improved arrival / departure routes’ and ‘optimised departure profiles’ but the text was not prescriptive for departures as opposed to the specific mention of CDO. The European Joint Industry CDA action plan stated that ‘the implementation of CDO should not trigger unacceptable trade-offs in other operations (e.g. for non-CDO arrivals or for departures)’. In the guide to CDO implementation produced by EUROCONTROL and its ATM Partners, there were no further mentions of departure profile optimisation or of any impact that CDO implementation may have upon arrivals.

The ICAO manuals for CCO and CDO address this topic by stating that CCO and CDO are enabled by airspace and procedure design where both arrival AND departure routes are designed in order to enable a departing aircraft to climb without interruption to its climb profile while maintaining separation with arriving traffic.
The manuals state that where a trade-off between CCO and CDO is unavoidable, local decision-making and analysis should take into account that ‘the per-second fuel burn in climb is typically greater than in descent’. However, they also state that often ‘there is far more unnecessary level flight in the descent phase than in the climb phase’. Indeed, the European CCO / CDO Taskforce has already demonstrated that the total fuel / emissions / cost savings from optimising CDO are in the range of 10 times those available from optimising CCO regardless of the high fuel burned in the climb phase.

Therefore, there may be more benefits in optimising CDO as opposed to CCO - although this may depend upon local conditions - and a balance should be found between arrival and departure route optimisation. Guidance as to how this balance may be addressed, assessed or mitigated is not offered in the ICAO Manuals.

Various research, studies and operational assessments in the US and in Europe e.g. studies by ERAT, SESAR (VINGA), the Swedish Transport Agency and Avinor (through the Oslo ASAP Project), have shown that integrating the arrival and departure system with optimised environmental benefits may be possible but must be determined on a local level depending on local airspace and procedures. Guidance material should therefore offer the option of studying the potential benefits of both single system enhancement and an integrated CCO / CDO system.

One methodology for assessing the benefits of optimising CCO, CDO or a combined CCO / CDO system is shown in Figure 14:

![Figure 14: Methodology for assessing the benefits of optimising CCO, CDO or a combined CCO / CDO system](image)

**A.12 Management of Military and other airspace reservation**

One of the main contributory factors to CCO / CDO and vertical flight inefficiency is the sharing of airspace between civil and military airspace users. Depending on the activity conducted in the airspace, it can be reserved and activated on a temporary or permanent basis. Areas (see Figure 15) may be published as prohibited, restricted or danger areas or as areas established particularly for the purpose of military exercises and training. Other than prohibited areas, in which the flight of aircraft is strictly forbidden, most of these are areas in which the flight of aircraft is restricted in accordance with certain specified conditions. These conditions are specified in terms of time windows and level blocks.

The activation of a reserved area may restrict aircraft from flying their optimal climb or descent profile in the activation time window because they have to level-off below or above it, depending on whether they are departing or arriving.
Consequently, departing aircraft can no longer employ optimum climb engine thrust and climb speeds until they reach their cruising level, while arriving aircraft can no longer employ minimum engine thrust, ideally in a low drag configuration, prior to the final approach phase.

Figure 15: Military areas in Europe in 2018. Source EUROCONTROL SAAM

In order to limit the occupancy of the airspace reservations to the shortest time strictly necessary, the concept of Flexible Use of Airspace (FUA) was developed. FUA is based on the potential offered by adaptable airspace structures and procedures that are especially suited to temporary allocation and utilisation. There are three main levels of Airspace Management (ASM), corresponding to civil / military coordination tasks in a distinct and close relationship with each level having an impact upon the others. Of particular interest to the optimisation of vertical profiles is the tactical level of the ASM process, which consists of the activation, de-activation or real-time reallocation of the airspace and the resolution of specific airspace problems and / or individual traffic situations between Operational Air Traffic (OAT) and General Air Traffic (GAT).

A.13 Geographical Constraints

The geographical surroundings of an airport may also be considered when analysing the factors that influence CDO / CCO performance.

One such factor might be the proximity of other airports. This may contribute to increased complexity and increased vertical and horizontal flight inefficiency, especially if a TMA containing multiple airports is designed to focus on maintaining the efficiency of one single airport e.g. the prioritisation of traffic departing / arriving London Heathrow has a negative impact on the efficiency of traffic arriving and departing from London City airport.

The proximity of a big city can also be an impacting factor as noise abatement procedures might restrict flight path availability. CDO has the biggest noise benefit approximately 6-20nm from an airport, depending upon local circumstances, while above FL100 (for departures, FL70 for arrivals), noise savings are negligible.

While the proximity of multiple airports may indeed have an impact on CCO / CDO performance, studies have shown that it is not specifically airport capacity that has the biggest impact on CCO / CDO performance. One of the conclusions of the ECAC study (see Figure 3) demonstrated that it is rather the traffic complexity in the core European airspace (represented by a circle of approximately 300nm centred on Luxembourg), that has a more significant effect on CDO performance.
Another example of barriers caused by an airport’s surroundings is the presence of high terrain. Mountainous or hilly terrain, together with the horizontal geometry of the existing airspace/route structure restricts the space available for manoeuvring aircraft in the same way that a neighbouring airport does. Some airspace design solutions (e.g. Point Merge, EoR) require large volumes of airspace that might not be available close at individual airports. For example, the EoR procedures detailed in Appendix A10 demand an amount of horizontal free space that may not be available at certain airports, e.g. for the south configuration of Madrid Airport, due to the proximity of a mountain range.

**A.14 Safety and CCO / CDO**

The principal objective of ATM is the safe, orderly and expeditious handling of aircraft. All stakeholders agree that safety is paramount and any trade-offs should never involve safety. However, ATM must also take into account other KPAs such as capacity, cost efficiency, and environment.

The responsibility for aviation safety in Europe lies with EASA whose objective it is to establish and maintain a high uniform level of civil aviation safety in Europe by implementing common rules in the field of civil aviation while also providing oversight to EU Member States. EASA is responsible for drafting implementing rules, which are binding in their entirety and used to specify a high and uniform level of safety and uniform conformity and compliance.

However, such prescriptive rules and guidance material may not be available to support enhanced environmental performance. Procedures to enhance performance, without prescriptive guidance or regulatory requirements, may result in more obstacles to implementation, as may be the case with the environment KPA compared to available procedures for a more regulated KPA such as safety.

This can be the case even if potential fuel and CO2 emissions savings may be achievable and substantial, like with CCO and CDO. This is because obtaining buy-in from operational staff (especially ATCOs and Flight Crews) for enhancing environmental performance is essential. This is not the same for safety with such binding rules and regulations.

There is also a real need to break down the barriers in helping ATCOs to first understand the environmental benefits and then, to be proactive in promoting and carrying out the operational changes – that is, to develop or maintain a similar mentality to the one they have for safety.

So, when considering the interdependencies between different KPAs or between different impacts in the environment KPA, or even between climb and descent profiles, the approach should be to have a collaborative process between stakeholders to ensure that all impacts from any operational change are understood. With buy-in from all operational actors and no potential safety impact, environmentally beneficial changes can be implemented.
A.15 Weather and CCO / CDO

To find out if weather and vertical profile management are connected, Stockholm Arlanda Airport (ESSA) conducted an analysis of time in level flight (the proxy for CDO) versus different meteorological parameters that could be extracted from Meteorological Aerodrome Reports (METAR).

Precipitation, wind direction and speed, pressure, temperature and visibility were compared to the average time in level flight of arrivals (note that these factors were not independent: e.g. precipitation, low visibility and stronger winds may all be linked to lower pressure).

Precipitation:
Precipitation was found to have a large impact upon the average time in level flight - when there was precipitation (i.e. ‘true’ in Figure 16), the time in level flight was 18 seconds higher than when there was no precipitation. However, the next three bars (DZ – drizzle, RA – rain, SN – snow) indicate that the major contributing factor to the higher times in level flight was snow.

Wind speed
Wind speed was a large contributing factor to the average time in level flight: it was almost double for wind speeds above 21kts. Note that the stable wind conditions were read from METAR and any information on gusts was ignored.
Visibility
The highest times in level flight occurred when the visibility was low and they were almost twice as high as when the visibility was good. The reason for this was that in poor visibility conditions, the Flight Crews were more likely to fly the aircraft in a more conservative way using a stepped descent.

Temperature and Humidity – Effect of Anti-Ice Systems
Modern jet aircraft operating procedures require the use of engine anti-ice and / or wing anti-ice systems under certain environmental conditions, typically in a Total Air Temperature (TAT) range of -40°C to +10°C under the presence of visible moisture. Moisture is typically considered to be visible at less than 1.5km.

Engine icing may form unexpectedly and may occur when there is no evidence of icing on the windshield or other parts of the airplane. Once ice starts to form, accumulation can build very rapidly. Although one bank of clouds may not cause icing, another similar bank may well induce icing.

On most aircraft the use of anti-ice systems leads to increased engine revolutions per minute (RPM) in order to provide the necessary bleed air pressure. An increased engine RPM means engine thrust is greater than idle and will therefore affect the vertical profile during descent as profiles will become shallower than the usual angle. For example, for Boeing Next Generation (NG) aircraft, the descent angle will become +/- 2.8° and therefore the descent profile may be stretched by up to 10%, due to the higher engine thrust settings required for anti-ice system operation. This means that the ToD will be further out and this is why, when calculating the descent performance and distance needed, anti-ice ON normally adds on between 5-10% of the descent distance.

Boeing advises that proper descent planning is necessary in order to arrive at the initial approach fix at the correct altitude, speed, and configuration. The anticipated anti-ice use altitudes should be entered on the descent forecast page to assist the FMC in computing a more accurate descent profile. In unexpected icing conditions, solutions may be found by utilising engine anti-ice and maybe the wing anti-ice. This may result in a situation with increased speed (& drag) and speed brake usage, both of which result in increased fuel burn.

Weather – Conclusions on CCO / CDO
The weather data clearly shows that meteorological conditions affect the amount of time flown in level flight. In addition, weather may have secondary effects such as runway closures, reduced runway throughput, slower taxi speeds, runway configuration changes and associated airspace use, all of which have an important influence on flight efficiency.

It should also be recognised that flexibility is needed when analysing similar assessment results as some factors may be beyond the control of ATM. For these reasons, the comparison between CDO performance in different seasons at the same airport, or even between airports, might not be appropriate, as the meteorological conditions will differ greatly between them.
A.16 Interdependencies and conclusions

As described above, there are many factors influencing the efficiency of the climb / descent profiles and therefore contributing to the extent to which a CCO or a CDO may be flown. However, there is one main aspect that has not been fully addressed: the interdependencies between them.

The key to improving the efficiency of the descent profile is for ATCOs to be able to give flight clearances that enable the Flight Crew to fly as closely as possible to the optimal climb and descent profile. Such profiles are enabled by optimal airspace design; modern ATM tools that help Controllers manage the increasing flow of aircraft, and good Pilot techniques for correcting any deviation from the optimum flight path. For this, predictability of the flight path is essential.

However, for multiple reasons, the predictability of the flight may be disrupted. The flight might have to avoid unfavourable meteorological conditions or maintain separation or runway throughput and therefore it is sometimes difficult to measure the impact of one criteria or constraint upon CCO / CDO performance.

Safety is paramount and will never be compromised for the sake of optimised vertical profiles. Knowing or understanding the impact of each constraint upon the climb or descent profile and therefore the possibility of flying optimised CCO or CDO is a difficult task. To add complexity to the equation, when multiple constraints exist, understanding the interdependencies of the different constraints on the measured performance at a specific airport is a complex task.

On a network level, capacity is considered a high priority after safety. The last eNM measures for summer 2019 are a perfect illustration. Under normal conditions, in order to optimise the descent profile, ATCOs may be encouraged wherever possible and when the traffic situation permits, to relax RAD restrictions on a tactical basis to allow aircraft to cruise at more optimal higher levels, thus enabling CDO from higher levels / top of descent. Likewise, flexible or dynamic transfer conditions may enable more optimum handover levels in quieter traffic periods.

However, the eNM measures – used to maximise capacity in those parts of the Network that were particularly congested in summer 2019 – generated the temporary publication of several constraints and level cappings. This was to deal with the predicted demand, to avoid delays as far as possible and to ensure trajectory predictability. But these measures did reduce the possibility of coordinated restriction relaxation.

In such cases, there is no way to overcome these new constraints without affecting the performance of the whole network. Therefore, interdependencies on a network level should not be forgotten when addressing climb and descent profile optimisation on a local level.

Whereas safety is rightly seen as the first priority for the network, there is currently an enhanced awareness of the link between aviation emissions and climate change; indeed, in some cases, environmental savings are eclipsing capacity as the key priority after safety.

With the urgent need to demonstrate that the aviation sector is pulling its weight, the focus is on operational stakeholders and their ability to optimise the climb / descent profiles from ToD and to ToC to save as much fuel, and therefore, CO2 emissions, as possible. The demand for environmental savings will only increase: CCO and CDO may be seen as one of the last large-scale fuel and emissions saving operational improvements available to the ATM system.

On a local level, flight efficiency has to be balanced with local constraints – and these can be caused by local or network regulations. Removing constraints to optimise VFE is not a straightforward exercise. It should be discussed with all stakeholders involved to define the best trade-offs while considering the potential impact on safety, the environment, capacity and cost. Enabling a fully optimised climb and descent profile for every single aircraft (to ToC and from ToD) may not be a realistic target. It is the overall performance that must be addressed.
However, there is still room for improving the vertical flight efficiency of the climb and descent flight phases, by facilitating and enabling CCO / CDO to / from higher levels than is the case today. General performance improvement may be defined on a network level, but specific performance improvements should be decided on locally, after a proper analysis of the local constraints, the tools available and the correct degree of involvement and commitment of all stakeholders has been made. The appendices that follow describe proven solutions, tools, ongoing studies and European CCO / CDO Task Force outputs that support CCO / CDO implementation and optimisation of the climb and descent profiles.

Again, it has to be stressed that these are examples of how to improve efficiency in similar conditions. It could well be that, due to different conditions and local restrictions, some of the examples will not work for some airports. The emphasis should be on a collaborative approach by all local stakeholders.
The appendices contain potential solutions, stakeholder experiences, good practice guidance material and case studies to address the factors - detailed in Appendix A - that may impact the Flight Crews’ ability to fly CCO / CDO.