

# European CCO / CDO Action Plan



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# EUROPEAN ACTION PLAN FOR CONTINUOUS CLIMB AND DESCENT OPERATIONS (CCO AND CDO)

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# 1. EUROPEAN CCO / CDO ACTION PLAN

## 1.1. Acknowledgements

Working in partnership, the European CCO / CDO Action Plan, CCO / CDO Performance Dashboard and website of resources were developed with the support of stakeholders from across the aviation industry. The European CCO / CDO Task Force would like to thank the following stakeholders for their collaborative support:



## 1.2. List of acronyms

<b>A4E</b>	Airlines for Europe
<b>AAL</b>	Above Aerodrome Level
<b>a/c</b>	Aircraft
<b>ACARS</b>	Aircraft Communications Addressing and Reporting System
<b>ACC</b>	Area Control Centre
<b>ACFT</b>	Aircraft
<b>ACI</b>	Airports Council International
<b>AD</b>	Aerodrome (AIP)
<b>A/G</b>	Air / Ground
<b>ADS-B</b>	Automatic Dependent Surveillance - Broadcast
<b>AEM</b>	Advanced Emissions Model
<b>AeroMACS</b>	Aeronautical Mobile Airport Communication System
<b>AFE</b>	Above Field Elevation
<b>AIC</b>	Aeronautical Information Circular
<b>AIP</b>	Aeronautical Information Publication
<b>AIRAC</b>	Aeronautical Information Regulation And Control
<b>AIRE</b>	Airlines International Representation in Europe
<b>AMAN</b>	Arrival Manager
<b>AMDT</b>	Amendment
<b>AMSL</b>	Above Mean Sea Level
<b>ANP</b>	Aircraft Noise and Performance
<b>ANSP</b>	Air Navigation Service Provider
<b>AP</b>	Autopilot
<b>APC</b>	Approach Control
<b>APDSG</b>	ATM Procedures Development Sub Group
<b>APP</b>	Approach
<b>ASAP</b>	Advanced Sectorisation and Automation Project
<b>ASM</b>	Airspace Management
<b>ASTERIX</b>	All Purpose Structured EUROCONTROL Surveillance Information Exchange
<b>ATC</b>	Air Traffic Control
<b>ATCO</b>	Air Traffic Control Officer
<b>ATFM</b>	Air Traffic Flow Management
<b>ATM</b>	Air Traffic Management
<b>ATS</b>	Air Traffic Services
<b>AU</b>	Airspace User
<b>BADA</b>	Base of Aircraft Data
<b>CAA</b>	Civil Aviation Authority
<b>CAEP</b>	Committee on Environmental Protection
<b>CANSO</b>	Civil Air Navigation Services Organisation
<b>CAT</b>	Category
<b>CBT</b>	Computer Based Training
<b>CCC</b>	Common Core Content
<b>CCD</b>	Continuous Climb Departure
<b>CCO</b>	Continuous Climb Operation
<b>CDA</b>	Continuous Descent Approach

<b>CDO</b>	Continuous Descent Operation
<b>CEM</b>	Collaborative Environmental Management
<b>CFL</b>	Cleared Flight Level
<b>CFSP</b>	Computer Flight Planning Service Provider
<b>CI</b>	Cost Index
<b>CO2</b>	Carbon dioxide
<b>COCR</b>	Communications Operating Concept and Requirements
<b>CONOPS</b>	Concept of Operations
<b>COPAC</b>	Colegio Oficial de Pilotos de la Aviación Comercial
<b>COP</b>	Coordination Point
<b>CPDLC</b>	Computer Pilot Data Link Communications
<b>dB</b>	Decibel
<b>dBA</b>	Decibel (A weighted)
<b>DCT</b>	Direct
<b>DME</b>	Distance Measuring Equipment
<b>DT</b>	Displaced Threshold
<b>DTG</b>	Distance to Go
<b>eNM</b>	Network Manager summer measures
<b>EASA</b>	European Aviation Safety Agency
<b>EBAA</b>	European Business Aviation Association
<b>ECA</b>	European Cockpit Association
<b>ECAC</b>	European Civil Aviation Conference
<b>EMO</b>	Energy Management Operations
<b>ENR</b>	En-route (AIP)
<b>EoR</b>	Established on RNP
<b>EPP</b>	Extended Projected Profile
<b>ERAT</b>	Environmentally Responsible Air Transport
<b>ERM</b>	Environment Reference Material
<b>ERNIP</b>	European Route Network Implementation Plan
<b>ETFMS</b>	Enhanced Tactical Flow Management System
<b>EU</b>	European Union
<b>FAB</b>	Functional Airspace Block
<b>FAF</b>	Final Approach Fix
<b>FAP</b>	Final Approach Point
<b>FDM</b>	Flight Data Monitoring
<b>FDR</b>	Flight Data Recorder
<b>FHA</b>	Functional Hazard Analysis
<b>FIR</b>	Flight Information Region
<b>FL</b>	Flight Level
<b>FMC</b>	Flight Management Computer
<b>FMS</b>	Flight Management System
<b>FPA</b>	Flight Plan Angle
<b>FUA</b>	Flexible Use of Airspace
<b>GAT</b>	General Air Traffic
<b>GBAS</b>	Ground-Based Augmentation System

<b>GCD</b>	Great Circle Distance
<b>GEN</b>	General (AIP)
<b>GLS</b>	GBAS Landing System
<b>GM</b>	Guidance Material
<b>GND</b>	Ground
<b>GNSS</b>	Global Navigation Satellite System
<b>GW</b>	Gross Weight
<b>HFE</b>	Horizontal Flight Efficiency
<b>HMI</b>	Human Machine Interface
<b>hPa</b>	Hectopascal (Unit of Pressure)
<b>HTO</b>	High Transition Operations
<b>i4D</b>	Initial 4D Trajectory
<b>IANS</b>	Institute of Air Navigation Services
<b>IAF</b>	Initial Approach Fix
<b>IAG</b>	International Airlines Group
<b>IAP</b>	Initial Approach Point
<b>IAS</b>	Indicated Air Speed
<b>IATA</b>	International Air Transport Association
<b>ICAO</b>	International Civil Aviation Organisation
<b>ID</b>	Identification
<b>IFR</b>	Instrument Flight Rules
<b>IGS</b>	Increased Glide Slope
<b>ILS</b>	Instrument Landing System
<b>KPA</b>	Key Performance Area
<b>KPI</b>	Key Performance Indicator
<b>kts</b>	Knots
<b>LDA</b>	Low Drag Approach
<b>L-DACS</b>	L-band Digital Aeronautical Communications System
<b>Lden</b>	Day-evening-night noise level.
<b>LIDAR</b>	Light Detecting And Ranging
<b>LNAV</b>	Lateral Navigation
<b>LoA</b>	Letter of Agreement
<b>LoR</b>	Line of Responsibility
<b>LP/LD</b>	Low Power / Low Drag
<b>LPV</b>	Localiser Performance with Vertical guidance
<b>LTC</b>	Line Training Captain
<b>METAR</b>	Meteorological Aerodrome Report
<b>MLS</b>	Microwave Landing System
<b>MPL</b>	Multi-Crew Pilot License
<b>MRC</b>	Maximum Range Cruise
<b>NADP</b>	Noise Abatement Departure Procedure
<b>NEST</b>	Network Strategic Modelling
<b>NETOPS</b>	Network Operations
<b>NG</b>	New Generation
<b>nm</b>	nautical mile
<b>NM</b>	Network Manager
<b>NOTAM</b>	Notice To Airmen

<b>NOZ</b>	Noise Operating Zone
<b>NSA</b>	National Supervisory Authority
<b>OAT</b>	Operational Air Traffic
<b>OCO</b>	Optimised Climb Operations
<b>ODO</b>	Optimised Descent Operations
<b>ODP</b>	Optimised Descent Profiles
<b>OM</b>	Operations Manual
<b>PANS</b>	Procedures for Air Navigation Services
<b>PANS-ATM</b>	Procedures for Air Navigation Services – Air Traffic Management
<b>PANS-OPS</b>	Procedures for Air Navigation Services - Operations
<b>PBN</b>	Performance-Based Navigation
<b>PDB</b>	Performance Data Base
<b>PMS</b>	Point Merge System
<b>P-RNAV</b>	Precision – Area Navigation
<b>PRT</b>	Permanent Resume Trajectory
<b>QAR</b>	Quick Access Recorder
<b>QNH</b>	Q code for atmospheric pressure at sea level
<b>RA</b>	Resolution Advisory
<b>RAD</b>	Route Availability Document
<b>RCP</b>	Required Communication Performance
<b>RECAT</b>	Recategorisation
<b>RFL</b>	Requested Flight Level
<b>RMK</b>	Remark
<b>ROC</b>	Rate of Climb
<b>ROD</b>	Rate of Descent
<b>RPM</b>	Revolutions Per Minute
<b>RNAV</b>	Area Navigation
<b>RNP-AR</b>	Required Navigation Performance – Authorisation Required
<b>RP3</b>	Reporting Period 3
<b>RTA</b>	Required Time of Arrival
<b>R/T</b>	Radiotelephony
<b>RWY</b>	Runway
<b>SARPs</b>	Standards And Recommended Practices
<b>SASP</b>	Separation and Airspace Safety Panel
<b>SERA</b>	Standardised European Rules of the Air
<b>SESAR</b>	Single European Sky ATM Research
<b>SESAR JU</b>	SESAR Joint Undertaking
<b>SID</b>	Standard Instrument Departure
<b>SOP</b>	Standard Operating Practices
<b>SRAP</b>	Second Runway Aiming Point
<b>STAM</b>	Short-Term ATFM Measures
<b>STAPES</b>	System for Airspace Noise Exposure Studies
<b>STAR</b>	Standard Terminal Arrival Route
<b>SUPPs</b>	Regional Supplementary Procedures
<b>TA</b>	Tailored Arrival
<b>TAS</b>	True Air Speed
<b>TAT</b>	Total Air Temperature

<b>TBS</b>	Time Based Separation
<b>TCAS</b>	Traffic Collision Avoidance System
<b>TF</b>	Task Force
<b>TMA</b>	Terminal Manoeuvring Area
<b>ToC</b>	Top of Climb
<b>ToD</b>	Top of Descent
<b>UAC</b>	Upper Area Control Centre
<b>UK</b>	United Kingdom
<b>VFE</b>	Vertical Flight Efficiency
<b>VFI</b>	Vertical Flight Inefficiency
<b>VFR</b>	Visual Flight Rules
<b>VNAV</b>	Vertical Navigation
<b>VOR</b>	VHF Omni-directional Range
<b>V-PAT</b>	Vertical Profile Assessment Tool
<b>V/S</b>	Vertical Speed
<b>WA</b>	Working Arrangement
<b>XFL</b>	Crossing Flight Level
<b>XMAN</b>	Cross Border Arrival Management
<b>XTT</b>	Cross Track Reference



# EUROCONTROL

## 1.3. Statement of commitment

The aviation industry is facing substantial societal pressure to reduce aviation's environmental impact. One quick win would be to optimise flight efficiency as far as possible, using current knowledge, operational good practices and technological capabilities. Optimising the vertical flight efficiency in the climb and descent phases of flight through the enabling of Continuous Climb and Continuous Descent Operations (CCO and CDO) can help substantially reduce Aviation's environmental impact.

In collaboration with European aviation stakeholders, the European CCO / CDO Task Force has developed an updated version of the European Action Plan for CCO and CDO<sup>1</sup>. All stakeholders who have participated in the development of this Action Plan call for, and commit to, a step change in the facilitation, promotion and implementation of CCO / CDO with the objective of significantly reducing noise and CO<sub>2</sub> emissions.

The updated European CCO / CDO Action Plan urges all stakeholders to collaborate on optimising vertical flight efficiency and recommends a set of Key Principles that should be communicated on CCO / CDO. The Action Plan also highlights the main outcomes of the Task Force's work, in order to provide support to stakeholders and good practice guidance for CCO / CDO implementation.

## 1.4. Key principles of CCO / CDO

- Safety remains paramount;
- The updated CCO / CDO Action Plan proposes sets out shared and individual responsibilities for all ATM stakeholders so that they can play their part in implementing CCO / CDO and optimising vertical profiles;
- CDO is defined by ICAO in general terms (in order to harmonise design and operation) but in practice there are various ways of facilitating and executing a CDO - ICAO documentation gives generic guidance for the design of CCO / CDO procedures that fit most aircraft, but also describes how to facilitate the optimisation of descent profiles at the local level when the generic guidance may not be fully applicable;
- A step change in performance improvement is required when implementing CDO or optimising the descent profile from top-of-descent, where possible, taking advantage of the resources, guidance and good practice material detailed in the CCO / CDO tool kit;
- It should be understood that CDO is an aircraft operating technique, enabled by airspace and procedure design and facilitated by Air Traffic Control (ATC): all parties need to work collaboratively together to generate the benefits;
- Consideration of the impact on vertical profile efficiency for the climb and descent phases should be incorporated, from the beginning, in all airspace / procedure design projects to ensure that the optimisation of the climb / descent profile is taken into account from the earliest design stages;
- All airspace design guidance or relevant material e.g. ERNIP, ICAO Doc.9931, ICAO Doc. 9993, ICAO Doc. 8168 should be aligned and maintained / updated in accordance with the latest available information and research results;
- Although descent profiles can be optimised from any altitude, the focus should be to aim for an optimised descent profile from top-of-descent, while acknowledging potential interdependencies with other Key Performance Areas (KPAs) where there may be a fine balance to strike under certain situations e.g. between efficiency and capacity;
- Harmonised European CCO / CDO Performance measurements, CCO / CDO performance feedback to Flight Crews and Air Traffic Control Officers (ATCOs), focused ATCO / Flight Crew collaboration in the development of CCO / CDO procedures and operational changes, training for all stakeholders and the willingness of all stakeholders to communicate and undertake shared responsibilities to foster a performance improvement are all vital in delivering environmental savings and ensuring that this Plan succeeds;
- The decision on a methodology and metrics for performance measurements may be taken locally. However, performance measurements on an international level should be based on harmonised

1- The European CCO / CDO Action Plan together with the CCO / CDO performance dashboard and the resources, guidance and good practice material detailed on the European CCO / CDO Task Force webpages, constitute the CCO / CDO Tool Kit (<https://www.eurocontrol.int/articles/continuous-climb-and-descent-operations>)

definitions and methodology to make comparative performance measurement possible;

- Climb and descent performance is usually reported upon by an individual airport or airline. Factors that impact CCO / CDO performance e.g. airspace / procedure design together with the development of Letters of Agreement between ATC sectors, may be outside the airport's area of responsibility and so the individual airport itself may often not be accountable for sub-optimal performance. Nevertheless, airports can enhance CCO / CDO performance by sharing CCO / CDO performance measurements with stakeholders;
- It should be recognised that CCO / CDO performance measurement together with feedback on performance and 'best in class' performance benchmarking (e.g. comparing the performance of airlines A, B and C at Airport Z and not Airline A at Airports X, Y and Z) are vital enablers for improving CCO / CDO performance;
- A binary (CDO – Y/N) indicator for CCO / CDO is not recommended for performance measurement. This is because this type of indicator does not capture the level of inefficiency: it would not distinguish between a non-CDO that had experienced 30 seconds of level flight for separation purposes, and a non-CDO that had experienced 10 minutes of inefficient level flight, simply in order to comply with sub-optimal letters of agreement. Besides, such a binary approach might discourage efforts to implement minor positive changes such as performance improvements that would be invisible when using a binary indicator;
- The implementation of CDO should not trigger unacceptable trade-offs in other operations (e.g. for non-CDO arrivals or for departures);
- Platforms for the collaborative approach to environmental mitigation that can bring all stakeholders together, such as Collaborative Environmental Management (CEM<sup>2</sup>), can provide a means of addressing CCO / CDO implementation issues;
- Focused collaboration between ATCOs and Flight Crews when developing new CCO / CDO procedures or operational changes is vital for the implementation's success and the optimisation of the vertical profiles;
- Communications and training on CCO / CDO to and within stakeholder groups are essential – current levels

of communications and training on CCO / CDO to and within stakeholder organisations are not enough;

- Cross border operations and the local transfer of control agreements should be more optimally defined, where possible, in order to enable optimised vertical profiles through the removal of unnecessary vertical constraints and intermediate inefficient level segments. When constraints are necessary, "at or above" constraints compatible with the ICAO guidance should be applied in preference to "at or below" or "at" constraints, thereby encouraging aircraft to remain longer at higher flight levels, where fuel burn is typically lower and noise impact reduced; and,
- Research should continue into performance measurement in order to integrate aircraft characteristics such as fuel flow metrics for emissions and the use of speed brakes for noise purposes.

2- CEM is a Working Arrangement, developed by EUROCONTROL, that brings together the core operational stakeholders at airports: the airport operator, the main aircraft operators and the ANSP with the objective to identify the environmental impact of operational constraints and to enable a coordinated response that minimises these impacts whilst maximising the airport's current and future performance.



## 2. INTRODUCTION AND BACKGROUND

In March 2009, ACI, CANSO, IATA and EUROCONTROL released the CDA<sup>3</sup> Action Plan, which set out specific actions to be undertaken by the European aviation Industry in order to promote the rapid deployment of CDO for as many flights as possible.

The Action Plan was visualised as a living document with objectives to be updated should any significant new data emerge or mitigation techniques arise.

Since 2009, new operational and technical concepts have been developed and implemented while alternative sources of surveillance data have emerged. However, CCO / CDO implementation plans including the proposal to promote CDO as the art of the possible, have resulted in a fragmented approach to implementation. There have been misinterpretations of performance benefits due to conflicting definitions, performance targets that cannot be correlated with a network benefit and there has been no clarity on the quantification of the benefits that have been achieved in the network.

The European CCO / CDO Task Force was created in 2015 and developed the European CCO / CDO Action Plan to facilitate a step change in the provision of optimised vertical performance benefits at both the local and network levels.

The main goal of the Action Plan is to reduce the noise / fuel / emission impact caused by vertical flight inefficiency in the climb and descent phases. From the results of an ECAC-wide analysis<sup>4</sup> on CCO / CDO, it can be seen that the fuel / CO2 / cost savings from optimising CCO / CDO can provide substantial environmental and economic benefits (see Section 2.2 for more information) for stakeholders. Given that more than 10 years have passed since publication of the original Action Plan, the European CCO / CDO Task Force considers that it is the right time to release an updated Action Plan, containing key material with which stakeholders can work to optimise the efficiency of the climb and descent phases of flight.

### 2.1. What are CCO / CDO?

Continuous Climb and Descent Operations (CCO and CDO) are aircraft operating techniques enabled by airspace design, instrument procedure design and facilitated by ATC.

CCO and CDO allow aircraft to follow a flexible, optimum flight path that delivers environmental and economic benefits – reductions in fuel burn, gaseous emissions, noise and fuel costs - without any adverse effect on safety (see ICAO Doc 9993 and ICAO Doc 9931 respectively).

ICAO defines CDO as an aircraft operating technique:

*"enabled by airspace design, procedure design and facilitated by ATC, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix/final approach point (FAF / FAP). An optimum CDO starts from ToD (Top of Descent) and uses descent profiles that reduce Controller/Flight Crew communications and segments of level flight."*



3- For the purposes of this document, the terms CDO (Continuous Descent Operations) and CDA (Continuous Descent Approach) are interchangeable, likewise CCO (Continuous Climb Operations) and CCD (Continuous Climb Departure).

4- High levels results can be found in Paragraph 2.2 or at <https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations>

Where barriers exist to an idle descent, ATC should endeavour to provide support for the Flight Crew to fly an optimised descent profile in order to reduce noise at lower levels and reduce fuel burn throughout the entire descent profile.

With the removal of time flown level at inefficient intermediate altitudes due to intermediate constraints, these techniques result in more time being spent at more fuel-efficient higher cruising levels, hence significantly reducing fuel burn and lowering emissions and fuel costs. Therefore, when constraints are imposed, whenever possible they should be "at or above" constraints, thereby also supporting longer flight-times at higher altitudes (illustrated in Figure 1).

## 2.2. Benefits

Deployment of optimised CCO and CDO throughout Europe will be beneficial to all European ATM system stakeholders and will help the network to address the environmental challenges it faces.

EUROCONTROL studies (see below), SESAR studies<sup>5</sup> and ICAO analyses<sup>6</sup> have all previously estimated that the implementation of CCO and CDO can provide substantial fuel and emission savings when compared to non-CCO or non-CDO operations. Furthermore, CDO can contribute to a reduction in noise levels around airports (a CDO can reduce noise by SEL 1-5dBA<sup>7,8</sup>, compared to a non-CDO operation).

In 2018, the first ECAC-wide CCO / CDO study was undertaken using the harmonised definition, metrics and parameters for measurement identified by the European CCO / CDO Task Force.

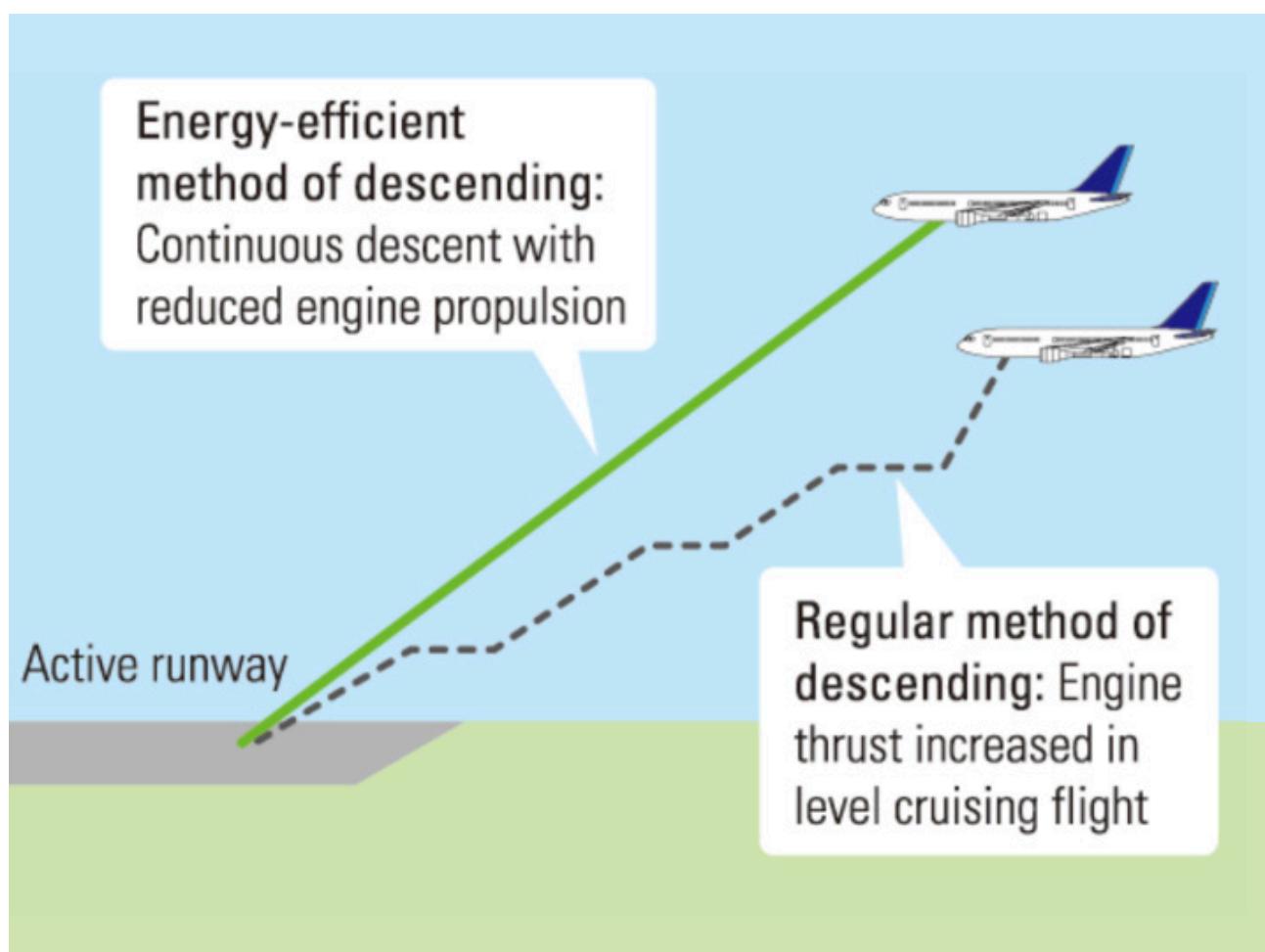


Figure 1: illustration of CDO benefits.



Figure 2 and Figure 3 show the results of this study based on the amount of time spent in level flight for both noise CCO / CDO and fuel CCO / CDO<sup>9</sup>.

The 2018 EUROCONTROL study revealed that the benefit pool from optimising the climb and descent phase (CCO / CDO) consisted of fuel savings of up to 350,000 tonnes per year for the airlines (that is, over 1m tonnes of CO2) or ~150 million €<sup>10</sup> in fuel costs. While these numbers represent a theoretical maximum of potential benefits, it is important to note that the achievement of 100% CCO and CDO across the European network may not be possible for a number of reasons. These include safety (i.e. the need to keep aircraft separated by a certain distance or time), weather, capacity or ATCO workload, all of which may be considered as inter-dependencies, while small inefficiencies in the system are required to operate a flexible and operationally efficient network.

It should also be noted that the estimated benefit pool in 2018 is more than double the benefit pool estimated in the 2009 CDA Action Plan. While fuel prices have decreased since 2009, according to EUROCONTROL statistics, IFR flight movements have increased by approximately 10% in the same timeframe indicating that the previous plan underestimated the amount of benefits available. Therefore, the results of the first ECAC-wide CCO / CDO benefits assessment in 2018 can concretely say that significant benefits can still be gained.

The main conclusions of this CCO / CDO benefits assessment were the following:

- The pool of potential performance improvements is much larger for the fuel CCO / CDO (CCO to top of climb / CDO from top of descent) compared to the noise CCO / CDO (low level) as the noise CCO / CDO are usually already optimised to a certain extent.
- The amount of time flown level (a proxy for inefficiency) in the fuel CCO / CDO demonstrates that there are significant benefits to be gained from optimising CCO to top of climb / CDO from top of descent compared to focusing upon low level CCO / CDO; and,
- The amount of time flown level (a proxy for inefficiency) in the climb phase is distinctly smaller (approximately x10) than the time flown level in the descent phase; therefore, the greatest fuel saving and emissions benefits will be achieved by optimising the descent profile.

That said, at certain airports the potential individual benefits from optimising CCO may still be greater than those from CDO. Therefore, the European CCO / CDO Task Force agreed that the departure profile would remain in the scope of Task Force work, even though the primary focus would be on generating the benefits to be gained from optimising the descent profile.

**For more information, see Appendix B.**

5- <https://www.sesarju.eu/news-press/documents/aire-2-reports-1034>

6- <https://www.icao.int/environmental-protection/pages/envrep2019.aspx>

7- Sustainable Aviation - <https://www.sustainableaviation.co.uk/wp-content/uploads/2018/06/A-Guide-to-CDOs-Booklet1.pdf>

8- <https://www.eurocontrol.int/publication/european-joint-industry-cda-action-plan>

9- For the definition of the noise CCO / CDO and the fuel CCO / CDO, see <https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations>

10- Based on 2018 fuel prices

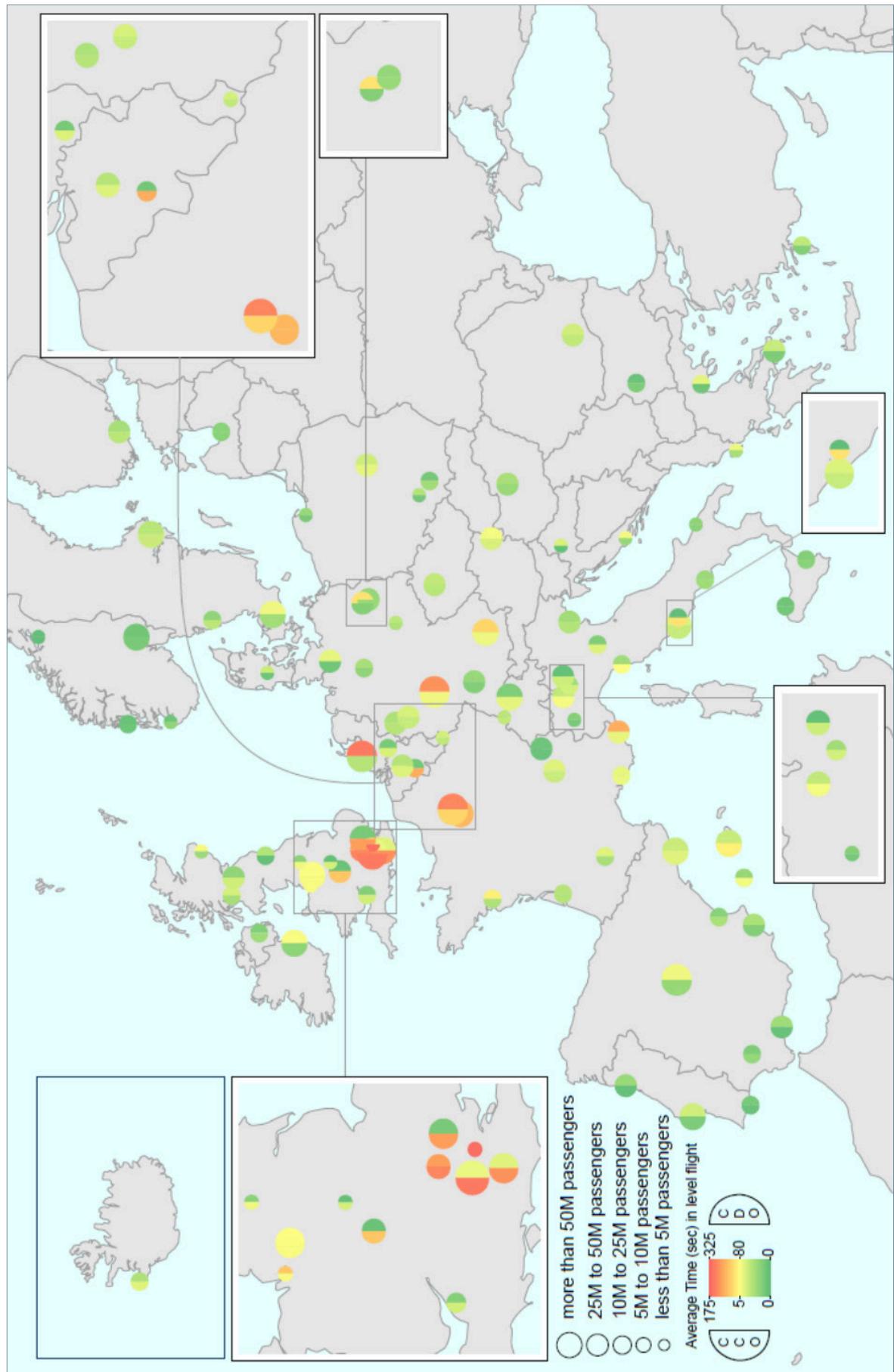


Figure 2: Noise CCO / CDO: Average time in level flight for all arrivals / departures (from FL75 / to FL105) at selected airports in 2017. Source: EAER with EUROCONTROL data

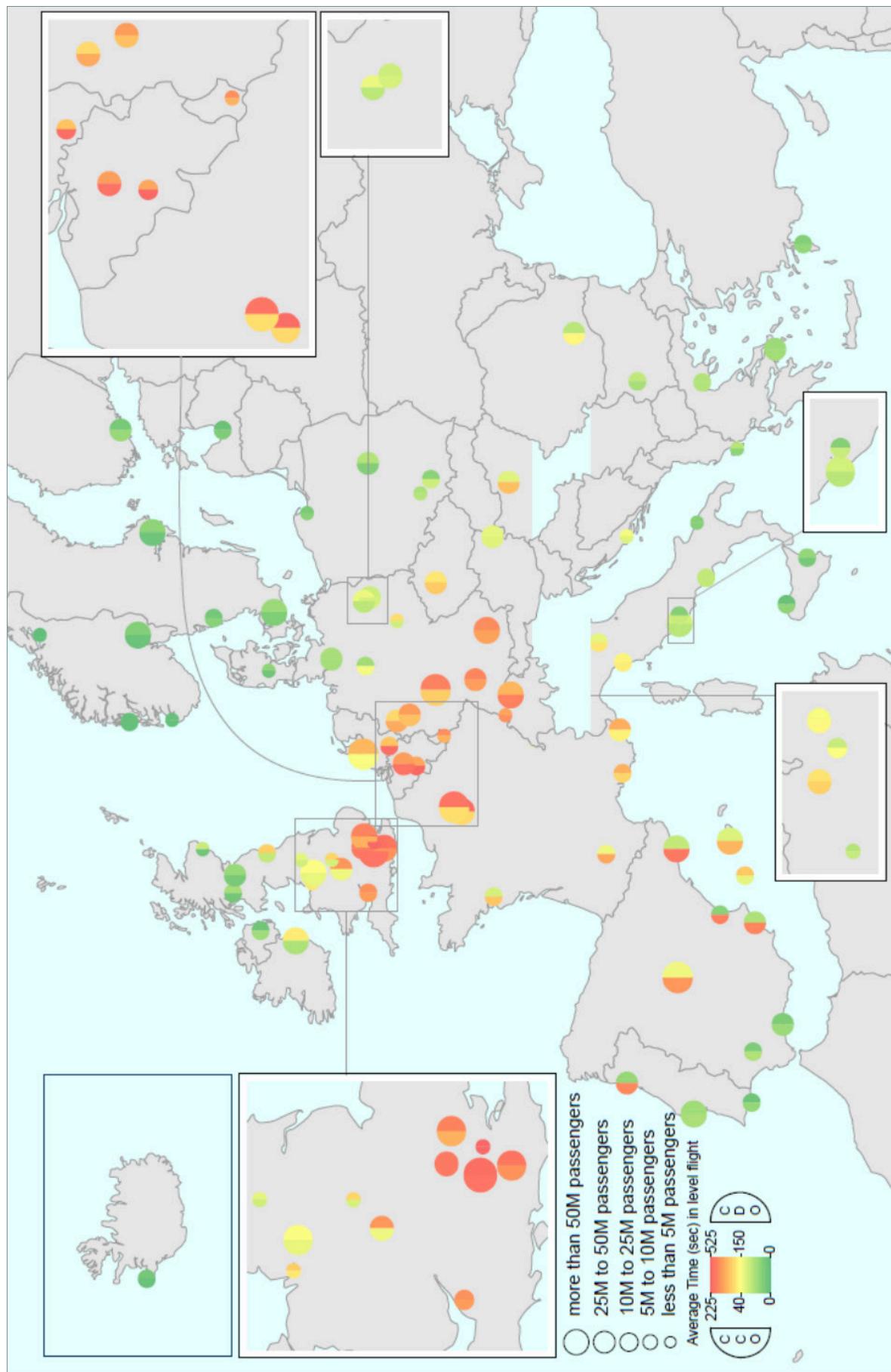


Figure 3: Fuel CCO / CDO: Average time in level flight for all arrivals / departures (from top of descent / to top of climb) at selected airports in 2017. Source: EAER with EUROCONTROL data

## 2.3. What has changed?

The NEW European CCO / CDO Action Plan was developed by the European CCO / CDO Task Force and calls for a step change in the facilitation, promotion and implementation of optimised climb and descent profiles (CCO / CDO) so that the significant noise, fuel burn, emission and fuel cost savings generated by these techniques can be realised by Stakeholders.

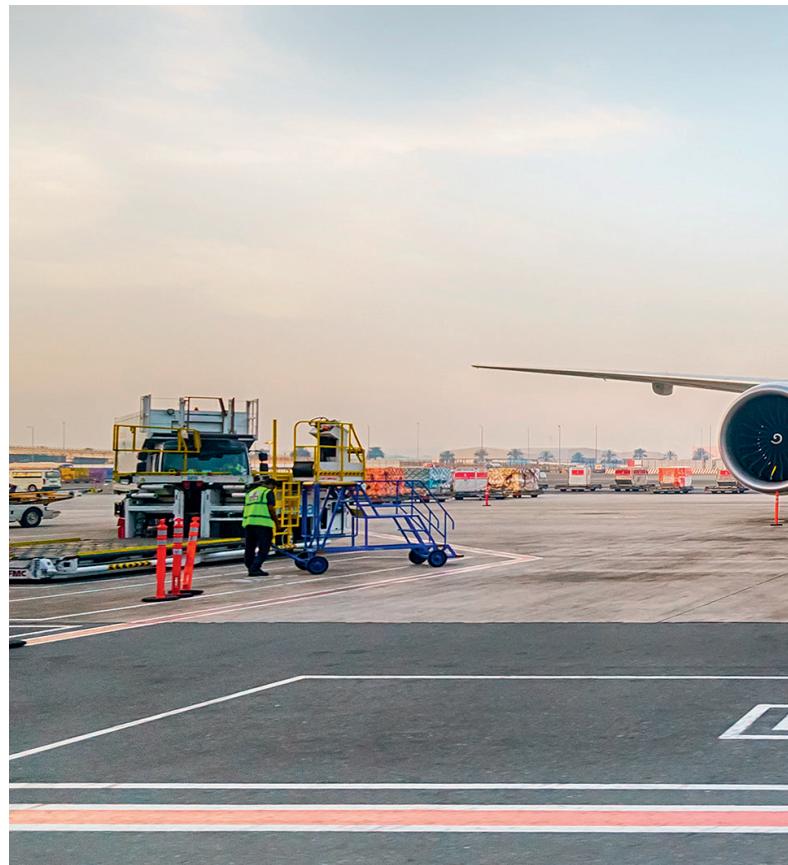
The objective of this Action Plan is to help stakeholders implement and optimise CCO and CDO across Europe. The Action Plan describes the latest technologies, procedures, harmonised performance measurement and stakeholder good practices for improved CCO / CDO facilitation, in order to enhance flight efficiency.

The Action Plan together with CCO / CDO performance dashboard<sup>11</sup> and a set of supporting resources detailed on the web pages of the European CCO / CDO Task Force, constitute the CCO / CDO Tool Kit. The objective of this Tool Kit is to provide information for stakeholders so that they can collaboratively implement more optimised climb and descent profiles and generate significant performance improvements for the climb and descent phases respectively.

In this Action Plan, Section 1 includes the Statement of Commitment from the Task Force members and authors of this Action Plan, who commit to collaborating on the optimisation of vertical flight efficiency and generating a step change in the facilitation, promotion and implementation of CCO / CDO. This commitment will serve the objective to significantly reduce the noise, fuel burn and CO2 emissions of individual flights. Section 1 also includes a set of Key Principles that the Task Force has identified to help stakeholders implement CCO and CDO and optimise climb and descent profiles.

Section 2 gives an introduction to CCO / CDO including background material on historical CCO / CDO work in Europe. It explains why the European CCO / CDO Task Force was created, gives key data on the potential environmental benefits available and describes the structure of the Action Plan.

Section 3 highlights the main outcomes of the European CCO / CDO Task Force on which this Action Plan will focus.



Critical enablers in optimising aircraft's vertical profiles are the need to address interdependencies and the sharing of responsibilities among ALL aviation stakeholders.

Section 4 includes the recommendations for both Shared and Individual responsibilities that the Task Force has identified as a way of underpinning the key principles. It should be borne in mind that many of these recommended actions do not only apply to a single stakeholder but also require collaborative actions by many stakeholders.

Appendix A describes a list of contributory factors that constrain the optimisation of the vertical flight efficiency of the climb and descent flight phases in European airspace. Each of these factors is explained in order to better understand how the complexity of each factor can limit optimised aircraft profiles together with the impact of the interaction of multiple factors. These factors should not be considered as barriers or excuses for non-implementation, but as factors that have a practical impact on the extent to which CCO / CDO can be flown. Consequently, there is an understanding that 100% efficiency may not be achievable, especially in the core area, due to the interdependencies between these factors.

Appendices B to Q detail a set of outcomes and actions that the European CCO / CDO Task Force has developed collaboratively to provide resources that can be used by aviation

11- Available at:  
<https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations>



stakeholders to support CCO / CDO implementation and to optimise existing performance in the face of the constraints imposed by such contributory factors.

These outcomes and actions include potential solutions, good practices and case studies to address the contributory factors detailed in Appendix A, those that may impact the ability to fly CCO / CDO.

These Appendices are specifically designed so that the reader can go straight to the appropriate section of interest without having to trawl through the entire Action Plan.

These outcomes and actions include *inter alia*:

- Harmonised definitions and metrics for measuring CCO / CDO performance;
- The introduction of Europe-wide monthly CCO / CDO performance for all Airlines and Airports, on the CCO / CDO performance dashboard;
- The creation of ATCO refresher training on aircraft energy management;
- A proposal for a Computer-Based Training (CBT) and associated visual aids to support Aircraft Operator refresher training materials;

- New proposals for ATCO and Flight Crew training objectives on CCO / CDO;
- Enhanced guidance in airspace and procedure design to facilitate CCO and CDO;
- A proposal for an airline CDO Policy together with supporting guidelines based on existing Aircraft Operator good practices; and,
- The sharing of good practices and case studies on CDO implementation, performance monitoring and collaboration.

Where possible, good practices or potential solutions are detailed respectively as case studies in these appendices.

**To avoid any doubt, all recommendations are to be read as "subject to the requirements of safety".**

### 3. THE TASK FORCE'S MAIN OUTCOMES

The European CCO / CDO Action Plan contains the deliverables and outcomes of the work of the European CCO / CDO Task Force. These outcomes will support stakeholders in the implementation of CCO / CDO by proposing harmonised metrics and performance measurements, training materials, good practice guidance material and case studies. These outcomes include:

- ✓ A detailed update of the estimation of the fuel / noise benefit pool that could be achieved by optimising CCO / CDO;
- ✓ A proposal for the use of harmonised CCO / CDO definitions, metrics and parameters for CCO / CDO measurement, agreed collaboratively by European aviation stakeholders;
- ✓ An analysis of the benefits differential between optimising low level CCO / CDO (noise CCO / CDO) compared to CDO / CCO from ToD / to Top of Climb (ToC - fuel CCO / CDO). The benefit pool for performance improvements from the noise CCO / CDO is much smaller than that for the fuel CCO / CDO as the former has already been fully optimised in Europe in a large number of cases;
- ✓ The development of monthly airline / airport statistics on CCO / CDO performance (<https://www.eurocontrol.int/articles/continuous-climb-and-descent-operations>) for ALL European airports and ALL airlines flying in Europe as defined by the harmonised definitions of the CCO / CDO Task Force;
- ✓ Updates to the EUROCONTROL Specification for ATCO Common Core Content training material related to CCO / CDO and aircraft energy management;
- ✓ A recommendation for the explicit use of CCO / CDO supporting material to be included in Flight Crew ab-initio and refresher training;
- ✓ A recommendation that airspace users develop specific standard operating practices (SOPs) on CDO and ensure that CDO material and good practices are systematically shared among all operational staff;
- ✓ The development of principles of airspace and procedure design which enable and facilitate optimised CCO / CDO, as detailed in the [European Route Network Improvement Plan \(ERNIP\) Part 1](#). These principles should be included as an integral part of airspace design both nationally and at the network level for all airspace changes and take into account the impact of any level / speed restrictions on optimised flight profiles;
- ✓ Aviation stakeholders should undertake regular reviews of Letters of Agreements (LoAs) between sectors and FIR boundaries to ensure that they take representative aircraft type characteristics into account and minimise, as far as possible, the amount of time spent in level flight between airspace sectors;
- ✓ The development of harmonised material on CCO / CDO; a harmonised structure and content to be located in a harmonised section of States' Aeronautical Information Publications (AIP). This material will take existing European AIP good practices into account;
- ✓ The vital need for close ATCO / Flight Crew collaboration in developing and implementing any new CCO / CDO procedure or airspace change;
- ✓ All industry stakeholders should ensure they work together to optimise CCO / CDO, while understanding the various interdependencies, and facilitate information-sharing via an appropriate platform e.g. CEM ;
- ✓ Manufacturers are encouraged to continue working on improving FMS capabilities and flight profile calculators to make them more efficient;
- ✓ Industry stakeholders should work together on developing the proper systems to increase the amount of information shared by aircraft and ATC systems; and,
- ✓ Research should continue into performance measurement in order to integrate fuel flow into future performance metrics where possible.

## 4. RESPONSIBILITIES

Multiple stakeholders are involved in the European aviation system. The responsibility for enabling, implementing and performing CCO / CDO operations does not rest with one individual stakeholder. CDO in particular, is an aircraft operating technique enabled by airspace and / or procedure design and facilitated by ATC. Even so, vertical flight efficiency improvements are not the responsibility of just the Flight Crews, the airspace / procedure designers or ATC. **It is a shared responsibility.**

If the European aviation stakeholders foster a common spirit to work through their collective and individual responsibilities as detailed in this Action Plan, this will enable a significant performance improvement.

As described in Appendix A, there are various factors influencing the optimisation of vertical profile performance (e.g. safety, capacity etc.). Moreover, some of these cannot be mitigated or solved by a single stakeholder independently and need to be addressed in a collaborative process where any interdependencies between different performance areas or users' 'needs' should be thoroughly discussed.

ALL stakeholders should therefore play a collaborative role in optimising vertical flight efficiency so as to ensure that the expected benefits are realised and the most optimal trade-offs between environment, capacity and cost efficiency are obtained.

In addition to the key actors - Air Navigation Service Providers (ANSPs), ATCOs, Aircraft Operators / Flight Crews and airspace and / or procedure designers - the optimisation of vertical profile performance may include other stakeholders such as Airport Operators, Regulatory Authorities, the SESAR Joint Undertaking (SESAR JU) and the Network Manager amongst others. It should be noted that this is a non-exhaustive list as different States may have different responsibilities shared by additional stakeholders.



In the context of this Action Plan, the **Airspace Designer** is responsible for the design of the airspace and to create an efficient, flexible and dynamic airspace structure, based on multi-option routeings and areas of Free Route operations, supported by adaptable ATC sectorisation; a structure that will accommodate future air traffic demand and meet the SES Performance requirements.



The **Procedure Designer** works closely with the Airspace Designer. The Procedure Designer is responsible for implementing the airspace designer's airspace design concept and ensuring that it complies with ICAO criteria e.g. 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.



An **ANSP** is a body that provides the service of managing air traffic on behalf of a company, region or country.



An **Aircraft Operator** (or Airline) is the owner of an aircraft or any employee of such owner or any person who has the authorised use of such aircraft for the purpose of its operation.



An **Airport Operator** is an organisation responsible for the direction and management of one or more airports. In some States, the Airport Operator may also be an ANSP.



The **Network Manager** is a transversal central function that manages the European air traffic management network functions. These include European Route Network Design, Air Traffic Flow Management and the coordination of scarce resources (radar transponder codes, radio frequencies), as defined in Commission Implementing Regulation (EU) No 2019/123.



**Regulatory Authorities** are national and European authorities that supervise the ATM Regulatory framework in ECAC States. They are responsible for certification, oversight and regulation of all aspects of civil aviation. They may include National Supervisory Authorities (NSAs) and / or Civil Aviation Authorities (CAAs). The European Union Regulator is the European Union's European Aviation Safety Agency (EASA).



The **SESAR Joint Undertaking** (SESAR JU) is responsible for defining, developing, validating and delivering technical and operational solutions to modernise Europe's ATM system and deliver benefits to Europe and its citizens.

The tables on the following pages define the responsibilities that are recommended for each stakeholder together with references to where related guidance material may be found in this Action Plan.



## 4.1. Shared responsibilities - recommendations for all Stakeholders

#	Responsibility	Actor(s) involved	Guidance material
1.1	Encourage collaboration with ALL industry stakeholders to ensure the appropriate dissemination of CCO / CDO related information to the members; all stakeholders should promote awareness of the fuel savings / environmental benefits that can be achieved by optimising vertical profiles.	ALL	Appendix B Appendix C Appendix N
1.2	On an international level (and nationally, if not subject to national regulations), outside of mandatory SES reporting mechanisms, CCO / CDO performance measurements should be based on the harmonised European definitions, metrics and parameters for measurement, as defined in this Action Plan.	ALL	Appendix B Appendix C
1.3	Use the resources of the CCO / CDO Tool Kit (the European CCO / CDO Action Plan, CCO / CDO Performance Dashboard and the associated website of resources) to enhance the efficiency of vertical profiles (and to encourage the implementation of CCO / CDO to / from the highest levels available so as to reap as many benefits as possible.	ALL	All appendices
1.4	Ensure that CCO / CDO techniques are a priority in airspace change and ATM performance initiatives.	ALL	Appendix E Appendix F
1.5	Ensure that the principles of ERNIP are followed and that CDO-enabling principles that support the optimisation of vertical profiles are followed as an integral part of the airspace or procedure change process.	ALL	Appendix E Appendix F Appendix G
1.6	Support the regular updating of the CCO / CDO Action Plan in the light of ATM developments together with ongoing developments in CCO / CDO capabilities and enablers that optimise vertical profiles e.g. PBN airspace design.	ALL	All Appendices
1.7	Promote the use of a collaborative forum bringing together all the relevant operational stakeholders using an established platform e.g. CEM, where operational improvement proposals, and the sharing of good practices relating to the optimisation of vertical profiles initiatives, can be discussed. It should be noted that the stakeholders who should be involved implementing CCO / CDO may include ATC authorities that are not in the immediate vicinity of the airport in question – membership may be invited on a temporary basis.	ALL	Appendix N Appendix Q
1.8	Collaborate in the regular and systematic review of Letters of Agreement (LoAs) between sectors and FIR boundaries to ensure that they take representative aircraft type characteristics into account. These LoAs should also minimise the number of vertical constraints and therefore the amount of time spent at inefficient intermediate level segments between airspace sectors. When constraints are necessary, they should be the least restrictive possible, using in particular "at or above" constraints in preference to "at or below" or "at" constraints.	ALL	Appendix G
1.9	Engage where possible with aircraft manufacturers to collaborate on concepts or new features that may optimise vertical profiles and facilitate more CCO / CDO e.g. the Airbus Idle Factor Optimiser.	ALL	Appendix O
1.10	Encourage the development of ATM concepts and CNS capabilities that enable the future sharing of trajectory intent data together with FMS parameters such as top of descent point.	ALL	Appendix O

Table 1: Shared responsibilities for all Stakeholders



## 4.2. Recommendations for Airspace / Procedure Designers

#	Recommendation	Action	Guidance
2.1	Optimise each specific approach procedure at the local level, as there is no single solution that will optimise the procedure and airspace design at all airports.	Airspace / Procedure designers	Appendix F
2.2	Develop each approach procedure in close collaboration between the ANSP, the Aircraft Operators, and, where necessary, the Airports, as an optimised design should take both the constraints and requirements of each party into account.	Airspace / Procedure designers	Appendix F Appendix N Appendix Q
2.3	Ensure that the principles for enabling CCO / CDO that facilitate optimised vertical profiles in the airspace and procedure design process, as detailed in the ERNIP document, are fully integrated into the airspace design process at both national level and network level.	Airspace / Procedure designers ANSP Network Manager	Appendix F Appendix G
2.4	When developing an ATC CONOPS, it should ideally be tailored to the implementation of vertical profile optimisation and should avoid the use of Open-ended STARs as far as possible. Closed STARs offer the predictability to fly an optimum descent profile.	Airspace / Procedure designers ANSP	Appendix F
2.5	Climb and descent routes should be designed to be as laterally independent of each other as far as possible. When choosing between the optimisation of the vertical and lateral profiles of the procedures, it should be borne in mind that each case will have a local solution. As a rule of thumb, if level segments are unavoidable, they should take place as high as possible in the procedure.	Airspace / Procedure designers	Appendix F
2.6	Airspace design should include the design of arrival and departure routes together. Simulations evaluating the effect of random variations of input variables are useful in evaluating likely trajectories, and can be used to optimise crossing levels as well as the trade-offs of various choices based on specific cases and locations.	Airspace / Procedure designers	Appendix F
2.7	There is a need to be flexible when designing an arrival route - airspace and procedure design usually takes into account 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 during specific times / days / seasons or under specified conditions.	Airspace / Procedure designers	Appendix F
2.8	As far as possible, arrival routes should follow the optimum idle descent path of the most common aircraft profiles, for each individual runway bearing in mind aircraft weights, prevalent winds, temperatures, speed schedules and optimum descent angles etc. Rules of thumb are available for supporting generic descent route creation; however, it is recommended that modelling of the local traffic mix should be used.	Airspace / Procedure designers	Appendix F
2.9	Arrival routes should be designed to be as short as possible, with a minimum of constraints and restrictions (FMSs may be unable to handle closely located constraints). A reduced number of waypoints will heighten compliance when there are lateral and vertical constraints.	Airspace / Procedure designers	Appendix F
2.10	Make use of existing environmental assessment methodology (e.g. ICAO, SESAR) as part of the process to be followed in all proposed airspace / procedure design exercises.	Airspace / Procedure designers	Appendix F Appendix P
2.11	Consider restructuring the given airspace to adapt to CDO procedures. Airspace around a CDO procedure (especially on high capacity arrival routes into large hub airports) can be designed as one airspace controlled by one ATCO sector group – a 3D channel through the existing classic structure of upper and lower airspace.	Airspace / Procedure designers ANSPs	Appendix F

#	Recommendation	Action	Guidance
2.12	LoAs should be designed on a flexible basis so that they can be adapted to runway direction, high / low demand periods, seasonal traffic, week / weekend traffic patterns. LoAs should be regularly reviewed on an individual restriction basis. LoAs may benefit from the creation of new waypoints to enable a new, more optimal and higher Top of Descent point, or a more optimum descent profile. Such changes should be promoted during the regular LoA reviews.	Airspace / Procedure designers ANSP	Appendix G
2.13	Reduce the amount of precise level instructions in operational procedures and replace with 'at or above', or altitude window restrictions, where possible.	Airspace / Procedure designers	Appendix F Appendix H
2.14	Avoid unnecessary published level-off segments that are mandatory for all. If needed they should be designed at locations and altitudes where Flight Crews may change configuration or manage the kinetic energy.	Airspace / Procedure designers	Appendix F
2.15	Maintain awareness of: (i) the impact on flight profiles that are produced by control mechanisms such as vectoring and speed control, and (ii) the impact such control can have on vertical profile performance.	Airspace / Procedure designers	Appendix H Appendix I
2.16	Limit the use of speed restrictions and, when needed, tailor them to the traffic mix.	Airspace / Procedure designers	Appendix F
2.17	When designing SIDs / STARs and in tactical situations, be aware that current analyses may indicate that, whilst each case may be considered differently, where aircraft types are similar, it may be less penalising in terms of fuel burn, to prioritise a CDO / descending aircraft as opposed to a CCO / climbing aircraft, which is contrary to current thinking.	Airspace / Procedure designers ANSPs	Appendix H

Table 2: Recommendations for Airspace / Procedure designers



## 4.3. Recommendations for Air Navigation Service Providers

#	Recommendation	Action	Guidance
3.1	Ensure that the principles for enabling CCO / CDO that facilitate optimised vertical profiles in the airspace and procedure design process, as detailed in the ERNIP document, are fully integrated into the airspace design process at both national level and network level.	ANSP Airspace / Procedure designers Network Manager	Appendix F Appendix G
3.2	In collaboration with Airport Operators and Regulatory Authorities, ensure that all future airspace designs and arrival / departure routes facilitate efficient CCO / CDO operations.	ANSP Airport Operators Regulatory Authorities	Appendix F
3.3	Undertake ANSP CCO / CDO performance monitoring and provide airline feedback on performance to create the baseline for performance improvements.	ANSP	Appendix B Appendix C
3.4	In collaboration with the regulatory authorities, ensure that ATCO ab-initio, local competency and refresher training incorporates simulation exercises on optimising CCO / CDO, aircraft energy management and the impact that control mechanisms – such as vectoring and speed control - have on vertical profile performance.	ANSP Regulatory Authorities	Appendix I
3.5	Jointly initiate, and be an active part of, a systematic exchange of views between Airspace Users and ANSPs (and Aircraft Operators where appropriate) relating to procedures for implementing CCO / CDO and optimising vertical profiles. This should be performed both at the individual Flight Crew / ATCO level and at the institutional level, particularly at airline home bases.	ANSP Aircraft operators Airport operators	Appendix F Appendix N Appendix Q
3.6	In collaboration with Computer Flight Planning Service Providers (CFSPs), Airport Operators and Regulatory Authorities (where appropriate), develop AIP content on CCO / CDO based on a harmonised European structure and text; one which clearly details the implementation and availability of CDO to airspace users. Also, ensure that the AIP and STAR plates are maintained and updated with the latest harmonised content and structure - this content should include all relevant CCO- and CDO-related information.	ANSP Airport Operators Regulatory Authorities	Appendix E
3.7	When developing an ATC CONOPS it should ideally be tailored to the implementation of vertical profile optimisation and should avoid the use of Open-ended STARs as far as possible. Closed STARs offer the predictability to fly an optimum descent profile. However, where Open STARs are implemented, or vectoring is used to tactically control traffic flows, CDO should be facilitated by a reliable and accurate provision of Distance to Go (DTG) information to provide maximum predictability of DTG for the Flight Crews and the FMS. Existing STAR profiles should be used consistently to enable predictability i.e. not to cancel them on a regular basis.	ANSP Airspace / Procedure designers	Appendix F
3.8	Promote the provision by ATCOs of accurate Track Miles or DTG during or before starting Open Path approach segments or when using vectoring wherever possible. This is an essential requirement to help Flight Crews calculate the optimal descent profile - ideally given before ToD, together with the publishing of DTG on STAR plates or integration in PBN procedure design. To help Flight Crews manage their descent, DTG may be provided as follows: <ul style="list-style-type: none"> <li>When first issuing descent clearance from the nominal top of descent point;</li> <li>After the aircraft changes frequency; or,</li> <li>At any time if a previous estimate has become invalid, e.g. following a new ATCO instruction or a change in landing sequence.</li> </ul>	ANSP	Appendix H

#	Recommendation	Action	Guidance
3.9	Promote the use of standard headings / speeds in the approach phase where possible, to facilitate systematic and predictable approaches.	ANSP	Appendix F Appendix H
3.10	Promote collaboration between Civil and Military Aviation administrators and integrate civil / military interactions in respect of optimised vertical profile concepts.	ANSP	N/A
3.11	Set up a LoA review process to systematically review LoA level requirements, adapt to any fleet mix changes and the updated route network / sectorisation / procedures, with neighbouring ANSPs and FIRs (within which level restrictions for departures / arrivals to / from your State may exist). This review process should ensure that LoAs do not unnecessarily restrict arriving / departing traffic with superfluous vertical constraints resulting in fuel penalties. Where possible, mutual agreements between ATC Units should also be encouraged by the ANSP to declare FL restrictions on LoAs, as "non-permanent" or "on request".	ANSP	Appendix G Appendix Q
3.12	LoAs should be designed on a flexible basis so that they can be adapted to runway direction, high / low demand periods, seasonal traffic, week / weekend traffic patterns. LoAs should be regularly reviewed on an individual restriction basis. LoAs may benefit from the creation of new waypoints to enable a new, more optimal and higher Top of Descent point, or a more optimum descent profile. Such changes should be promoted during the regular LoA reviews.	ANSP Airspace / Procedure designers	Appendix G Appendix Q
3.13	Bearing in mind the NM "file it, fly it" campaign to ensure predictability for ATCOs, ATFM Staff and NM should be encouraged, wherever possible and when the traffic situation permits, to relax RAD restrictions on a tactical basis. This allows aircraft to remain at more optimum (higher) flight levels for longer, and to waive vertical constraints so as to facilitate enhanced performance.  This enables the Flight Crew to further optimise the descent profile and may allow for tactical handovers to neighbouring sectors at more optimum levels than usual.  Coordination with neighbouring / downstream sectors may be required to ensure that any such relaxation of RAD restrictions will not unduly influence sector sequences or create overload situations in sectors handling the remaining trajectory of the flight concerned.	ANSP Network Manager	Appendix G
3.14	Promote the consistent use of ICAO Amendment 7A phraseology related to climb / descent clearances.	ANSPs Aircraft Operators, Regulatory Authorities	Appendix M Appendix Q
3.15	When designing SIDs / STARs and in tactical situations, be aware that current analyses may indicate that, while each case may be considered differently, where aircraft types are similar, it may be less penalising in terms of fuel burn, to prioritise a CDO / descending aircraft as opposed to a CCO / climbing aircraft, which is contrary to current thinking.	ANSPs Airspace / Procedure designers	Appendix H
3.16	Consider restructuring the given airspace to adapt to CDO procedures. Airspace around a CDO procedure (especially on high capacity arrival routes into large hub airports) can be designed as one airspace controlled by one ATCO sector group – a 3D channel through the existing classic structure of upper and lower airspace.	ANSPs Airspace / Procedure designers	Appendix F

Table 3: Recommendations for Air Navigation Service Providers



## 4.4. Recommendations for Aircraft Operators

#	Recommendation	Action	Guidance
4.1	Develop and follow a CCO / CDO policy (regarding both flight planning and operations). This policy should ensure that airline Standard Operational Practices (SOPs) on CDO are developed so that good practices relating to CDO can be shared with all Flight Crews in order to create awareness of such good practices.	Aircraft Operators	Appendix J
4.2	Integrate "CCO / CDO and Flight Crew awareness of CCO / CDO as a performance enabler" as a competency in Initial Line Training and recurrent refresher training. The competency should be based upon the CDO policy and SOPs and detail the noise, fuel burn and emissions savings that CCO / CDO can deliver.	Aircraft Operators	Appendix K
4.3	Undertake Airline CCO / CDO performance monitoring and provide Flight Crew feedback on performance, and carry out CCO / CDO performance benchmarking to create a baseline for performance improvements.	Aircraft Operators	Appendix B Appendix C Appendix L
4.4	Jointly initiate, and be an active part of, a systematic exchange of views between Airspace Users and ANSPs (and Aircraft Operators where appropriate) relating to procedures for implementing CCO / CDO and optimising vertical profiles. This should be performed both at the individual Flight Crew / ATCO level and at the institutional level, particularly at airline home bases.	Aircraft Operators ANSP Airport Operators	Appendix F Appendix N Appendix Q
4.5	Encourage Flight Crew to request ATC for track miles or Distance To Go (DTG) information, especially at lower levels in the descent - should it not be provided, to enable the Flight Crew to manage aircraft energy and to calculate the optimum descent profile.	Aircraft Operators	Appendix H
4.6	Maintain awareness of: (i) the requirements for ATC to maintain throughput and sequencing by using vectoring and speed control, and (ii) the impact such control can have on vertical profile performance and aircraft energy management.	Aircraft Operators	Appendix H Appendix J
4.7	Promote the consistent use of ICAO Amendment 7A <sup>13</sup> phraseology related to climb / descent clearances.	Aircraft Operators, ANSPs Regulatory Authorities	Appendix M Appendix Q

Table 4: Recommendations for Aircraft Operators



## 4.5. Recommendations for Airport Operators

#	Recommendation	Action	Guidance
5.1	In collaboration with ANSPs and Regulatory Authorities, ensure that all future airspace designs and arrival / departure routes facilitate efficient CCO / CDO operations.	Airport Operators Regulatory Authorities ANSP	Appendix F
5.2	Promote airport CCO / CDO implementation and execution.	Airport Operators	Appendix B Appendix C Appendix D Appendix Q
5.3	Undertake Airport CCO / CDO performance monitoring and provide airline feedback on performance to create the baseline for performance improvements.	Airport Operators	Appendix B Appendix C Appendix D Appendix Q
5.4	Promote policies to implement CCO / CDO at lower levels for noise and to ToC / from ToD for maximum fuel saving benefits.	Airport Operators Regulatory Authorities	Appendix B Appendix D
5.5	In collaboration with CFSPs, ANSPs and Regulatory Authorities (where appropriate), develop AIP content on CCO / CDO based on a harmonised European structure and text; one which clearly details the implementation and availability of CDO to airspace users. Also, ensure that the AIP and STAR plates are maintained and updated with the latest harmonised content and structure - this content should include all relevant CCO- and CDO-related information.	Airport operators ANSP Regulatory Authorities	Appendix E
5.6	Jointly initiate, and be an active part of, a systematic exchange of views between Airspace Users and ANSPs (and Aircraft Operators where appropriate) relating to procedures for implementing CCO / CDO and optimising vertical profiles. This should be performed both at the individual Flight Crew / ATCO level and at the institutional level, particularly at airline home bases.	Airport Operators Aircraft operators ANSP	Appendix F Appendix N Appendix Q

Table 5: Recommendations for Airport Operators



## 4.6. Recommendations for the Network Manager

#	Recommendation	Action	Guidance
6.1	Collaborate with the work of the European CCO / CDO Task Force to ensure that CCO and CDO and optimised vertical profiles are integrated into network operations in a practical fashion.	Network Manager	Appendix F
6.2	Monitor CCO and CDO performance at the network level and inform stakeholders about performance levels on a regular basis.	Network Manager	Appendix B Appendix C
6.3	<p>Bearing in mind the NM “file it, fly it” campaign to ensure predictability for ATCOs, ATFM Staff and NM should be encouraged, wherever possible and when the traffic situation permits, to relax RAD restrictions on a tactical basis. This allows aircraft to remain at more optimum (higher) flight levels for longer, and to waive vertical constraints so as to facilitate enhanced performance.</p> <p>This enables the Flight Crew to further optimise the descent profile and may allow for tactical handovers to neighbouring sectors at more optimum levels than usual.</p> <p>Coordination with neighbouring / downstream sectors may be required to ensure that any such relaxation of RAD restrictions will not unduly influence sector sequences or create overload situations in sectors handling the remaining trajectory of the flight concerned.</p>	Network Manager ANSP	Appendix G
6.4	Ensure that the principles for enabling CCO / CDO that facilitate optimised vertical profiles in the airspace and procedure design process, as detailed in the ERNIP document, are fully integrated into the airspace design process at both national level and network level.	Network Manager Airspace / Procedure designers ANSP	Appendix F Appendix G

Table 6: Recommendations for the Network Manager



## 4.7. Recommendations for the Regulatory Authorities

#	Recommendation	Action	Guidance
7.1	In collaboration with Airport Operators and ANSPs, ensure that all future airspace designs and arrival / departure routes facilitate efficient CCO / CDO operations.	Regulatory Authorities Airport Operators ANSP	Appendix F
7.2	Implement a policy to support CCO / CDO implementation and execution on both local and international levels.	Regulatory Authorities	Appendix B
7.3	In collaboration with CFSPs, Airport Operators and ANSPs (where appropriate), develop AIP content on CCO / CDO based on a harmonised European structure and text; one which clearly details the implementation and availability of CDO to airspace users. Also, ensure that the AIP and STAR plates are maintained and updated with the latest harmonised content and structure - this content should include all relevant CCO- and CDO-related information.	Regulatory Authorities Airport Operators ANSPs	Appendix E
7.4	In collaboration with the ANSP, ensure that ATCO ab-initio, local competency and refresher training incorporates simulation exercises on optimising CCO / CDO, aircraft energy management and the impact that control mechanisms – such as vectoring and speed control - have on vertical profile performance.	Regulatory Authorities ANSP	Appendix I
7.5	Promote policies to implement CCO / CDO at lower levels for noise and to ToC / from ToD for maximum fuel saving benefits.	Regulatory Authorities Airport Operators	Appendix B Appendix D
7.6	Promote the consistent use of ICAO Amendment 7A phraseology related to climb / descent clearances.	Regulatory Authorities ANSPs Aircraft Operators	Appendix M Appendix Q
7.7	Support States in implementing Amendment 7A SID / STAR phraseology including sharing training material that may be found on the ICAO public website.	Regulatory Authorities	Appendix M

Table 7: Recommendations for Regulatory Authorities



## 4.8. Recommendations for the Sesar Joint Undertaking

#	Recommendation	Action	Guidance
8.1	Promote the inclusion of topics in support of the optimisation of vertical profiles in the research and development roadmap.	SESAR JU	Appendix O

Table 8: Recommendations for the SESAR Joint Undertaking





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

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<sup>14</sup>; and,
- For latest generation i4D FMSs, RTA function in the descent phase to meet a time constraint with greater precision +/- 10 seconds<sup>15</sup>.

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.

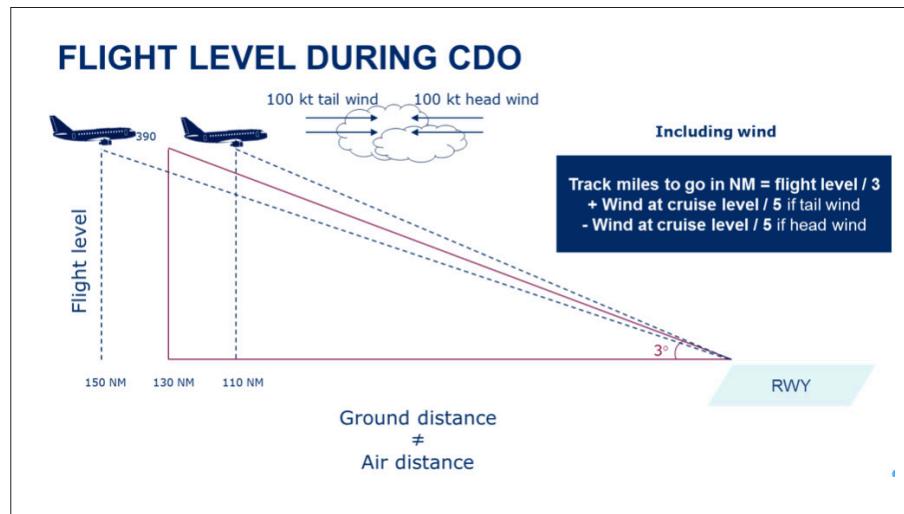


Figure 4: Rule of thumb for a 3-degree descent profile

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. through 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.

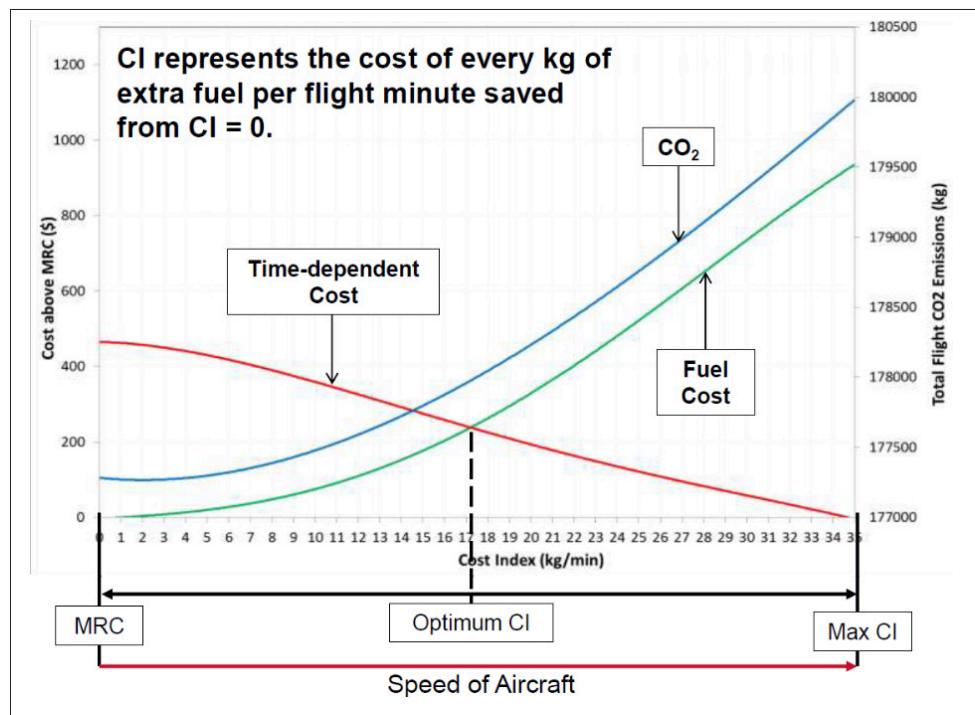


Figure 5: Cost index impact on fuel

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.

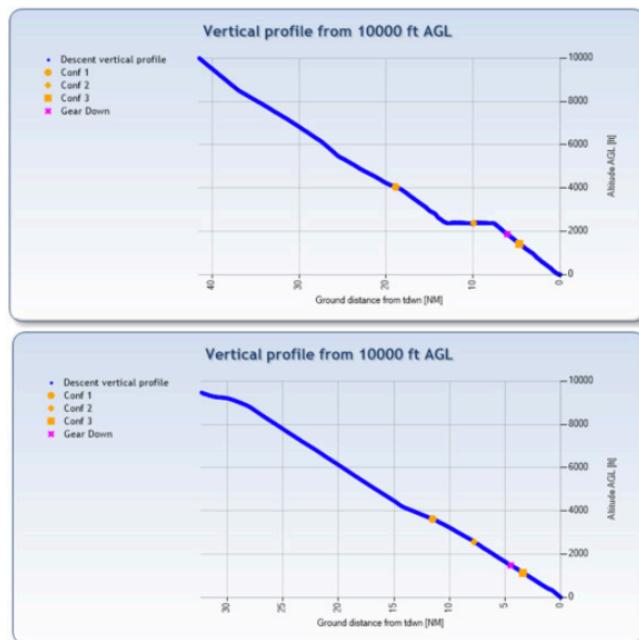


Figure 6: difference in profile with the new Airbus CDO features (A321)

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

16- <https://www.sesarju.eu/newsroom/brochures-publications/optimised-descent-profiles-odp>

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 in 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<sup>17</sup>, 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<sup>18</sup>. 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<sup>19</sup>. 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)

18- <https://www.easa.europa.eu/document-library/acceptable-means-of-compliance-and-guidance-materials/reg/atco---air-traffic-controllers>

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.

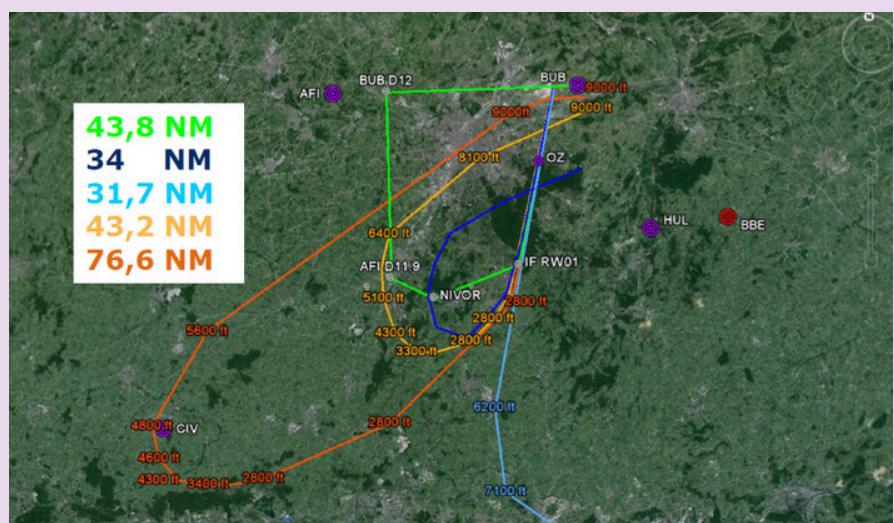


Figure 7: Unpredictability of the vectoring at RWY01 at EBBR (Source: Brussels Airlines)

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 / CO<sub>2</sub> 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.

## RAD LEVEL-CAPPING AS A NETWORK CAPACITY ENABLER

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.

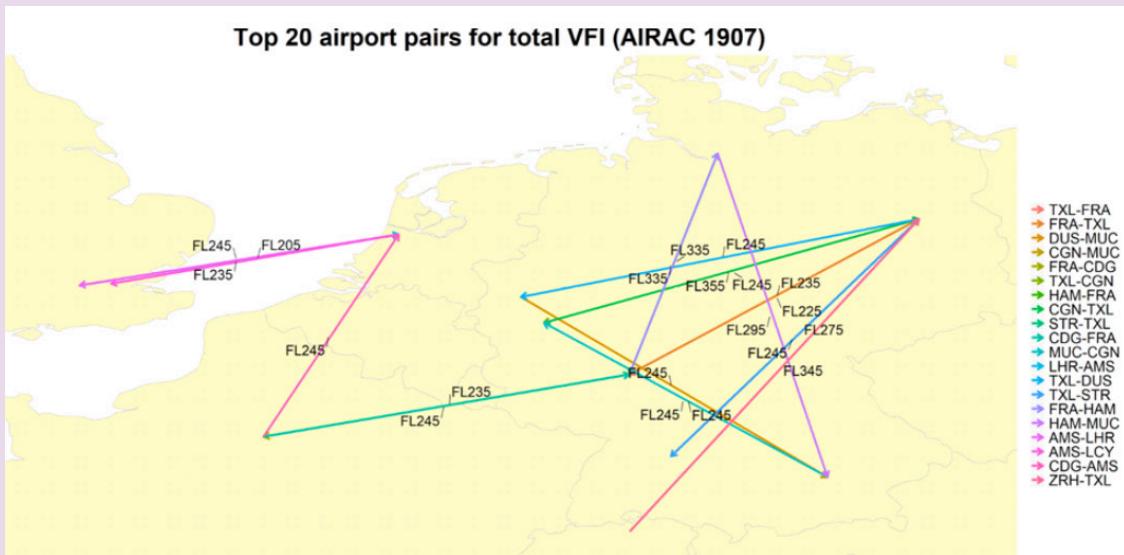


Figure 8: Top 20 airport pairs for total vertical flight inefficiency (AIRAC 1907)

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.

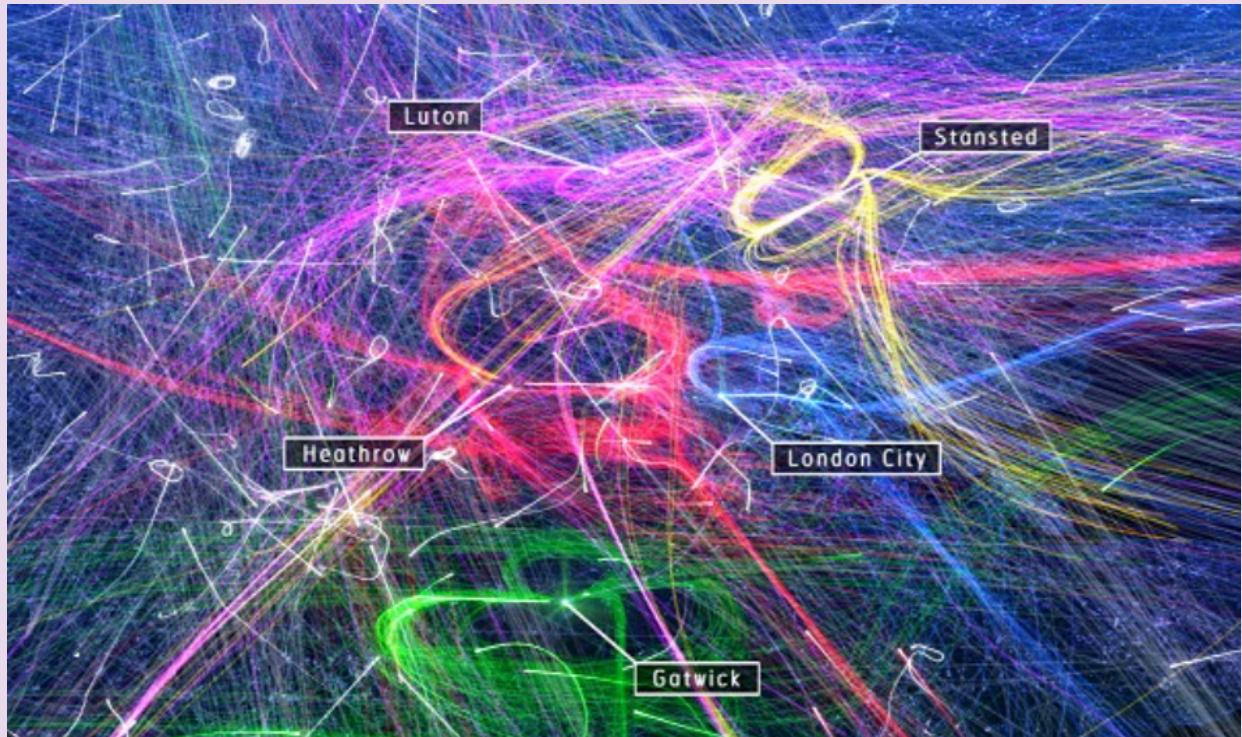


Figure 9: Visualisation of traffic in London TMA, including its racetrack holding patterns.

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.

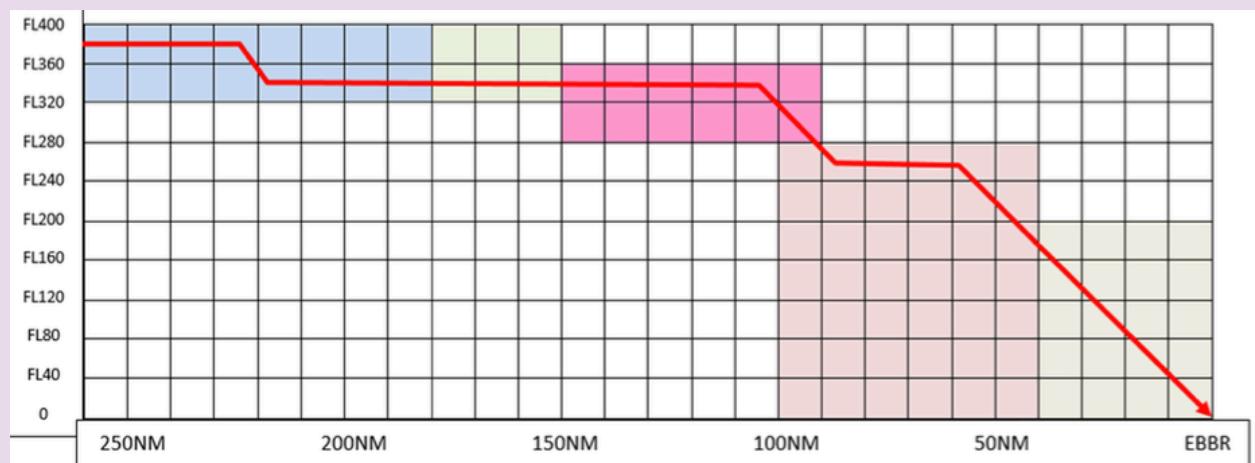


Figure 10. An inefficient vertical profile due to LoAs/RAD restrictions into EBBR (Source: TUIfly)

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).<sup>20</sup>

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.

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20- <https://www.eurocontrol.int/publication/european-route-network-improvement-plan-ernip-part-1>

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)

## ILLUSTRATION OF BASIC CDO DESIGN (FROM ICAO DOC 9931)

Vertical constraints should whenever possible, be designed so that they do not penalise aircraft flying a continuous descent using a descent rate between 220ft/nm and 350ft/nm, which covers the optimum descent rate for most aircraft. Figure 11 illustrates this case.

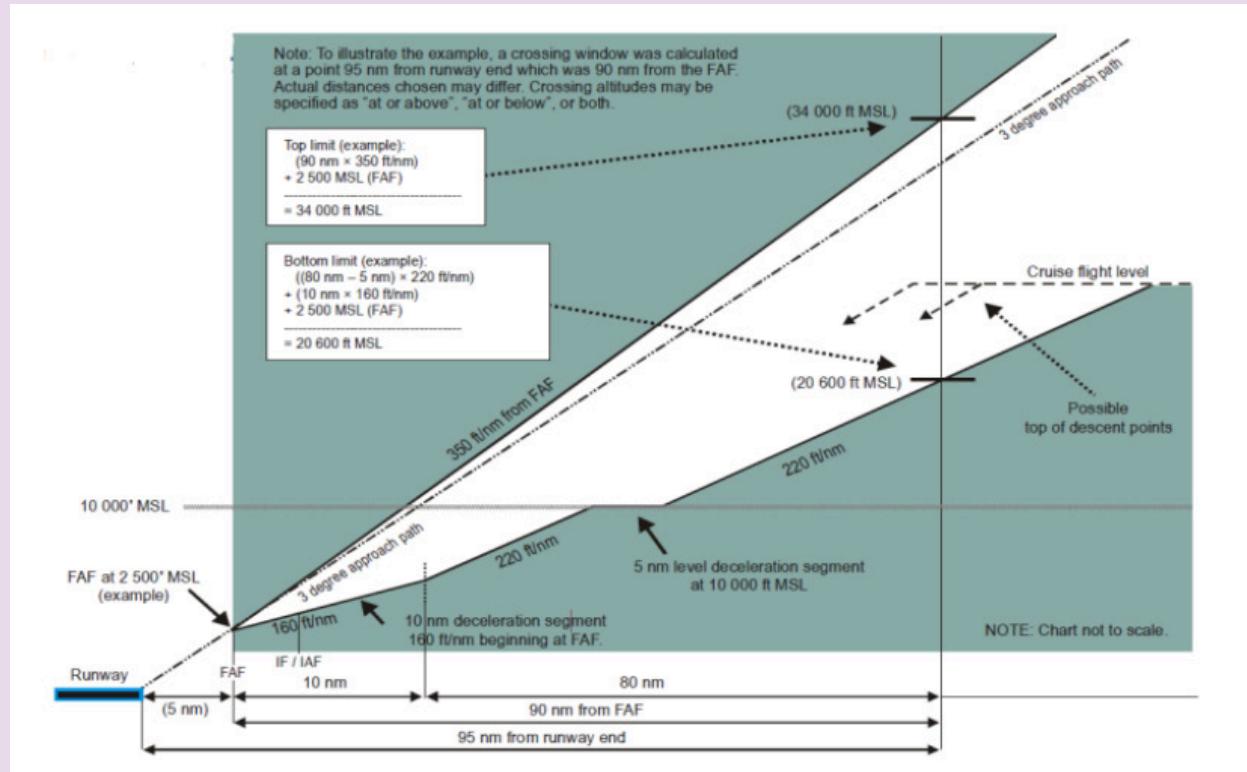


Figure 11. Design of CDO procedure as per ICAO document 9931 allowing the full range of 220-350ft/ min descent rates

When the crossing windows cannot be set to allow the full 220-350ft/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/nm (instead of the 220 - 350ft/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 solutions<sup>21</sup>. Where Open STARs are implemented, optimum profiles and the provision of DTG may still be enabled by the use of support tools.

21- SESAR solutions 62 "P-RNAV in complex TMA", SESAR solution 11, "CDO Using point merge", SESAR solution 51 "Enhanced terminal operations with RNP transition to LPV", SESAR solution 9 "Enhanced terminal operations with automatic RNP transition to ILS/GLS", SESAR solution 10, "Optimised route network using advanced RNP".

## 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<sup>22</sup> 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.

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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.

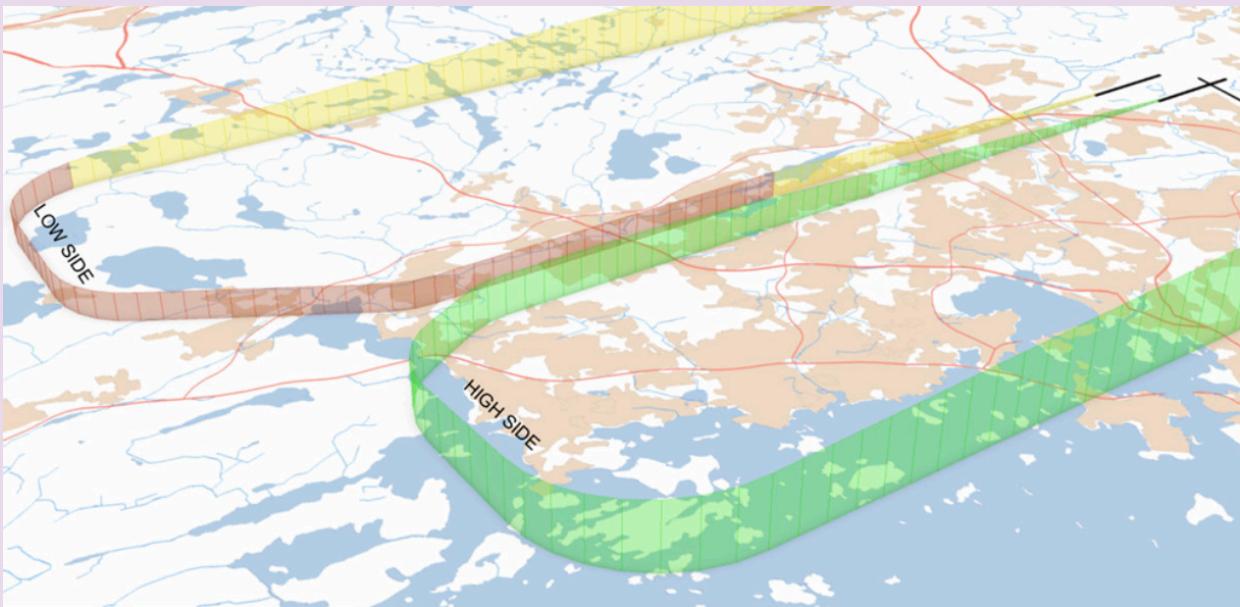


Figure 12: Example of independent parallel approaches in use

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 in-

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.

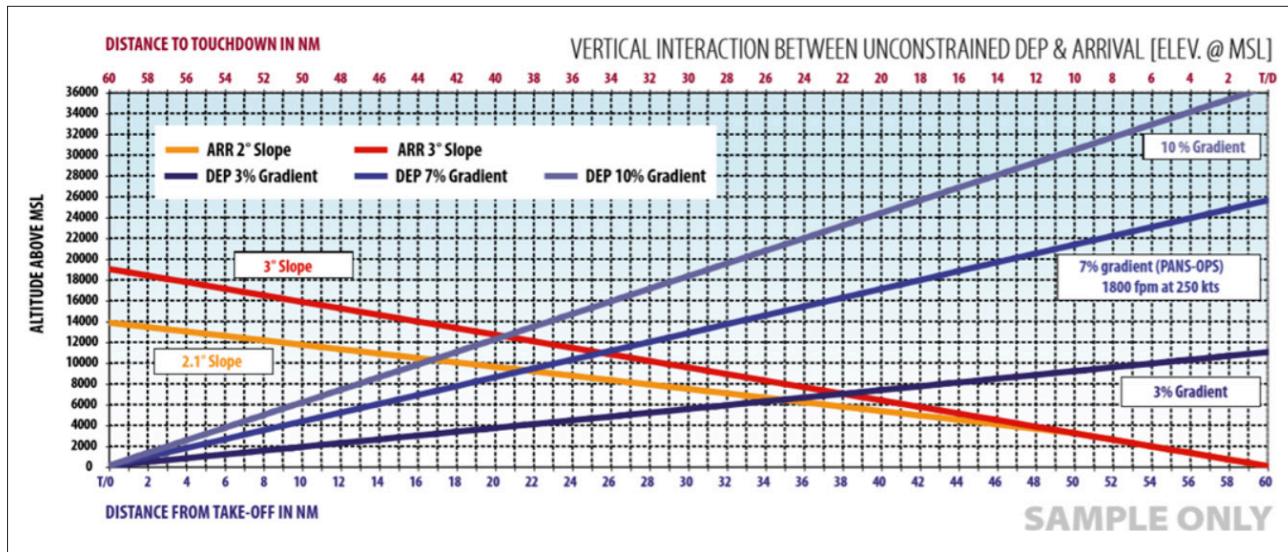


Figure 13: interactions between CCO and CDO profiles. Source: European Airspace Concept Handbook for PBN Implementation

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:

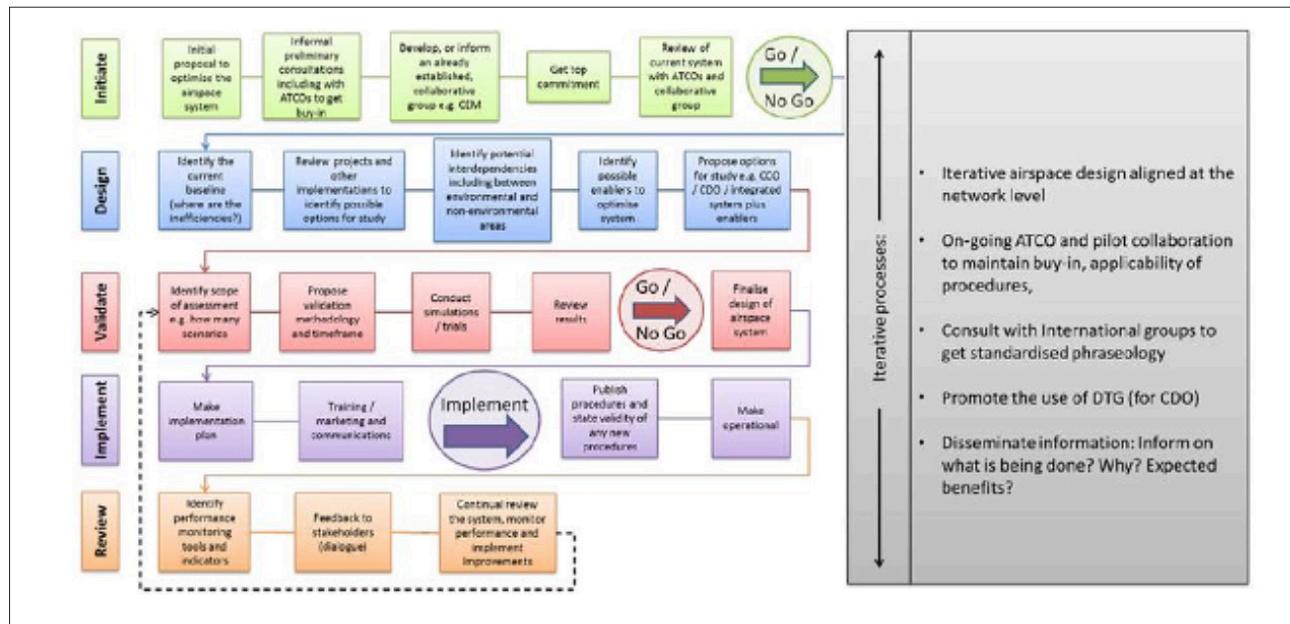


Figure 14: Methodology for assessing the benefits of optimising CCO, CDO or a combined CCO / CDO system

## 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.

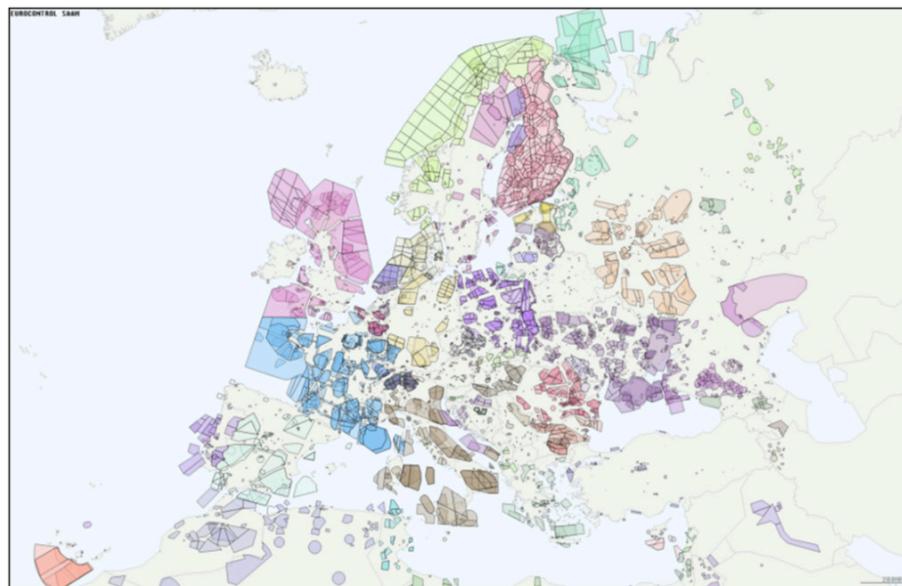


Figure 15: Military areas in Europe in 2018. Source EUROCONTROL SAAM

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 to 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 CO<sub>2</sub> 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.

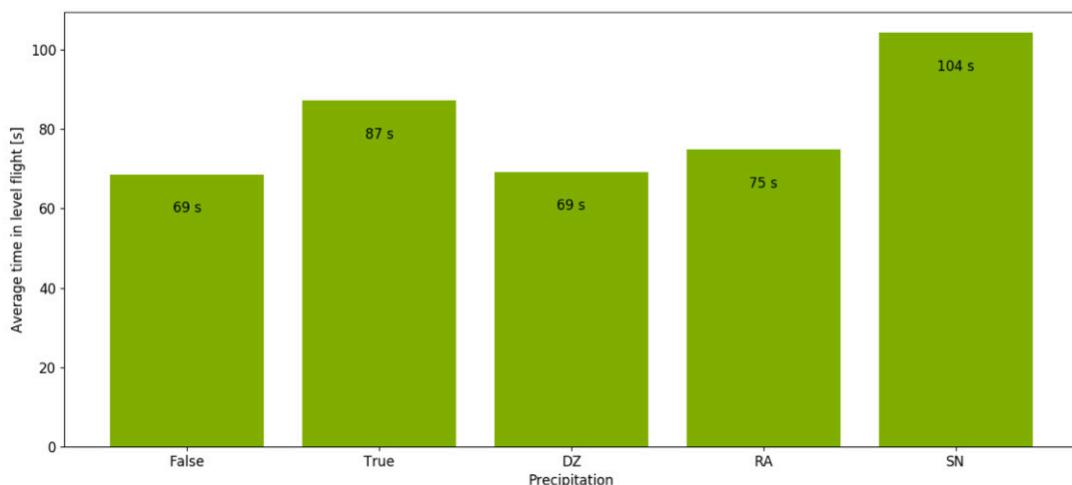


Figure 16: impact of precipitation upon time in level flight (CDO) at ESSA

### 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.

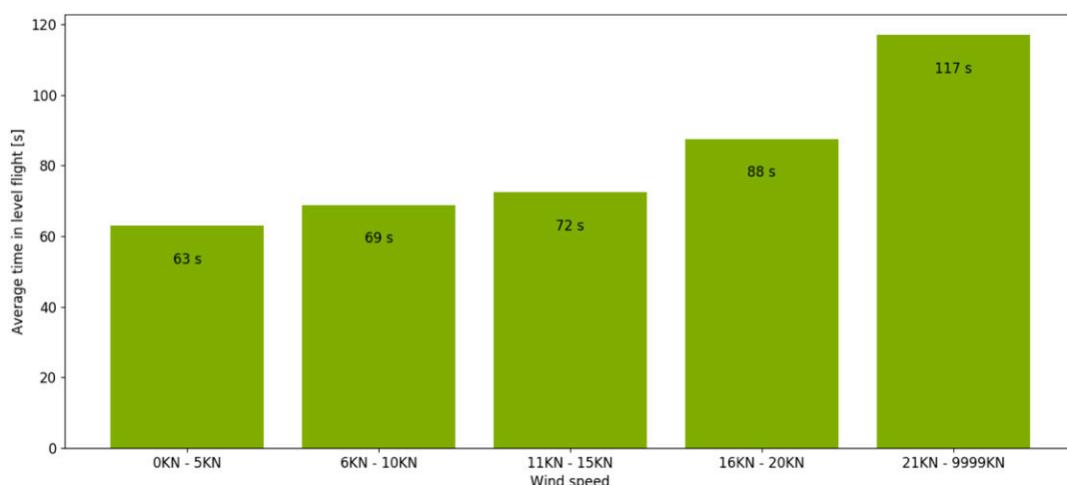


Figure 17: impact of wind speed upon time in level flight (CDO) at ESSA

## 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.

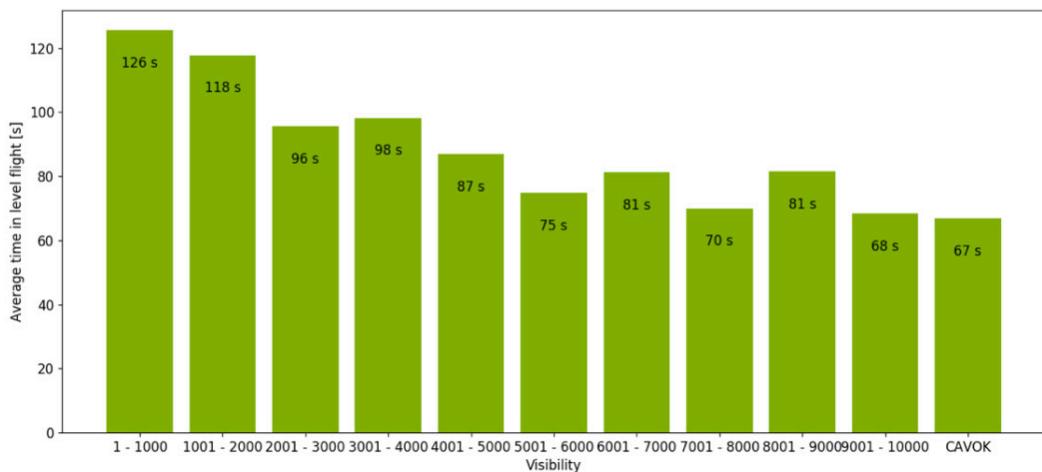


Figure 18: Impact of visibility upon time in level flight (CDO) at ESSA

## 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.**



## APPENDIX B: HARMONISED METRICS FOR CCO / CDO MEASUREMENT

### KEY MESSAGE

**The European CCO / CDO Task Force has defined a set of harmonised definitions, metrics and parameters for CCO / CDO measurement, agreed collaboratively between European aviation stakeholders, to enable a comparative CCO / CDO performance measurement across Europe.**

**On an international level (and the national level, if not subject to national regulations), outside mandatory SES reporting mechanisms, the Task Force strongly recommends that CCO / CDO performance measurements should be based on these harmonised European definitions.**

In 2016, the European CCO / CDO Task Force delivered a set of Stakeholder-agreed definitions, metrics and parameters for harmonised European CCO / CDO measurement. These outcomes included:

- A harmonised definition of both a noise and a fuel CDO;
- A harmonised definition of both a noise and a fuel CCO; and,
- A harmonised set of metrics and parameters for CCO / CDO measurement relating to the average time in level flight in seconds.

The Fuel CCO / CDO measures the vertical flight efficiency from / until top of descent / top of climb and evaluates the fuel / CO2 efficiency of the whole descent / climb profile.

The Noise CCO / CDO measures the vertical flight efficiency at lower levels (from FL75 / up to FL105)\* and evaluates that part of the descent / climb profile where SESAR considers the primary environmental impact to be noise.

\*The noise CDO may be measured from FL75 or 7500ft AAL (Above Aerodrome Level), although local exceptions may apply. The same applies for the noise CCO to FL105 or 10500ft AAL. When looking at the altitudes of level segments for the CCO / CDO performance dashboard (appendix C), the level segments will be grouped in level bands of 1000ft including the 500ft below and above a multiple of 1000ft in every band e.g. the band of 5000ft goes from 4500ft to 5500ft. This means that one level band will cover pressure variations of around 33 hPa in QNH.

Historically, metrics commonly used to measure CCO / CDO have relied on a percentage achievement level based on a binary indicator of whether there are any periods of level flight or not in a vertical profile.

It should also be noted that in February 2019, in the context of the Single European Sky initiative, COMMISSION REGULATION (EU) No 317/2019 was published which gives a set of Indicators for monitoring. They were prescribed for the third performance Reference Period (RP3) starting on 1st January 2020 and ending on 31st December 2024. The European Union-wide performance indicators will include a new environmental indicator for monitoring: the share of arrivals applying Continuous Descent Operation (CDO), calculated locally as follows:

- This indicator is the ratio between the total number of arrivals performing a CDO from a reference point at a height

above ground, defined by the national supervisory authority, and the total number of arrival operations. The criteria to define if it was a CDO or not is the detection of a level segment; and,

- This indicator is expressed as a percentage, calculated for the whole calendar year and for each year of the reference period.

This indicator is ideally suited to measure the performance of the part of the descent profile where noise is the principal environmental impact. While the altitude of the reference point to be defined by the national supervisory authority may depend on local factors such as airspace particularities or the extent of the area of responsibility of the national ATC authority, the majority of emissions savings can be gained from optimising the descent profiles from top of descent or from higher levels wherever possible. While reference points may be defined according to local requirements, airspace design should still aim at enabling CDO from top of descent or from as high a level as possible.

The European CCO / CDO Task Force is not in favour of this proposed regulatory approach. This is because:

- National Supervisory Authorities may select a reference point that is not as ambitious as it could be to provide a true performance improvement which is the objective of the Regulation;
- The pool of potential performance improvements (both noise and fuel) is much larger for the fuel CCO / CDO (CCO to top of climb / CDO from top of descent) compared to the noise CCO / CDO (low level) as the noise CCO / CDO are usually already optimised to a high degree;
- A binary (CDO – Y/N) performance measurement of CCO / CDO is not recommended as such an indicator does not reveal the full picture. An unavoidable 30 seconds of level flight for separation purposes is considered in the statistics to have the same performance impact as 10 minutes of level flight; and,
- The European Commission Regulation does not reflect work ongoing in Member States. This work may differ to that detailed in the Regulation with current performance measurements being more granular and of greater detail and use.

The Task Force therefore advocates, and has adopted, an indicator based upon average time in level flight (seconds), which takes into consideration the possible inefficiency in a quantitative way. Together with the altitude at which the level segment occurred, average time in level flight gives a better indication for analysing the causes and possible actions to be taken to achieve potential improvements.

In a constraint-free environment, aircraft would reach their optimal ToD and execute an idle-thrust continuous descent and, for departures, the optimum climb profile would be followed until the ToC. Therefore, the very presence of a level segment is an indicator of an inefficiency, one which may have several causes. Identifying such segments and their length provides valuable insights to ANSPs and airspace designers, allowing them to look for potential improvements.

The Task Force is fully aware of the actual pitfalls and potential errors of this indicator, as no aircraft flies alone in the sky. Once the optimum profile is not followed, neither the length of the level-off segments or even their very presence correlates perfectly with an increase in fuel burn. The reason for this is that should the aircraft already be below profile, depending on the situation, it could be actually better off in terms of fuel consumption by maintaining a level segment until the optimal profile can be re-joined. In this case, the word “continuous” does not necessarily mean the most optimal descent, as that level segment could actually be more efficient.

On the other hand, the Task Force notes that even though the existence of a level-off segment indicates that the complete vertical profile is not fully optimised, the absence of a level-off segment does not mean that the vertical profile is fully optimised. A profile can be continuous but sub-optimal, e.g. by restricting the rate of climb or descent, with the latter causing the descent to be performed without minimum engine thrust). In this case, the harmonised criteria metric would not account for that inefficiency.

While fuel burn data from Flight Data Recorders (FDR) may be considered the optimal way for measuring profile efficiency with regard to fuel burn, the unavailability of such data on a pan-European level precludes the use of such data, in addition

to legal exclusions in certain European States on the use of FDR data for performance measurement.

Some ANSPs are trying to develop tools that, through artificial intelligence, will be able to use available radar data for the efficiency analysis (see Appendix O), but this is not yet available on a systematic and pan-European level. Several alternative potential solutions, new researches and metrics have been presented, debated and addressed.

After lengthy discussion, the Task Force considers the average time in level flight to be the most appropriate proxy for the measurement of CCO / CDO based upon:

- The expertise of the Task Force and current stakeholder practices of measuring CCO / CDO;
- Research into other more accurate metrics, with the conclusion that there is no better currently available single geometric indicator that can be used to measure the efficiency of the vertical profile in terms of fuel;
- Data currently available for large-scale analysis; and,
- The fact that a straightforward measurement of fuel burn is not yet possible,

One note of caution should be that, as previously mentioned, the Single European Sky Performance Scheme has defined a CDO indicator based on a binary definition. In addition, many ANSPs or airports may also already monitor CDO performance using a binary indicator (using different criteria) or alternative indicators that fit their local needs. In this case, CDO performance measurement will differ when using different binary indicators or other local variants.

This variability in CDO measurements may confuse the public or the authorities as they are not aware of the different definitions. Therefore, the Task Force recommends that stakeholders make an effort to communicate to interested parties so that they may become aware of the different metrics that may be used including the harmonised definition as promoted by the Task Force.

The European CCO / CDO Action Plan's proposals for the use of harmonised performance indicators on CCO / CDO are not designed to supplant existing national regulatory requirements on CCO / CDO reporting, nor do they preclude ongoing research work for finding better ways of measuring performance.

Stakeholders are strongly encouraged to follow the harmonised definitions and parameters proposed in the Action Plan when measuring the efficiency of vertical profiles on an international or pan-European level. This will allow them to make a harmonised comparison of CCO and CDO performance, until any new or complementary metrics and criteria become available and are agreed on a European level.

For full details on how to measure CCO / CDO performance, visit  
<https://www.eurocontrol.int/articles/continuous-climb-and-descent-operations>  
or watch an animation found at <https://www.youtube.com/watch?v=mUkMPb5eVJI>.



## APPENDIX C: CCO / CDO PERFORMANCE MONITORING AND FEEDBACK ON PERFORMANCE

### **KEY MESSAGE**

**One of the key CCO / CDO performance enablers that has already been demonstrated to enhance performance is performance monitoring and the associated feedback on performance to stakeholders.**

**The European CCO / CDO Task Force is developing the performance dashboard to provide statistics on CCO/ CDO performance for all airports in Europe and all airlines that fly in Europe\*.**

**The performance dashboard can be found at**

**<https://www.eurocontrol.int/articles/continuous-climb-and-descent-operations>**

\*Subject to data availability

Recommendations 2.3, 3.2 and 5.2 in the responsibilities section recommend how stakeholders (for Aircraft Operators, ANSPs and Airport Operators respectively) should be promoting CCO / CDO performance monitoring together with the feedback on CCO / CDO performance to Aircraft Operators and Flight Crew. Appendix L deals specifically with Aircraft Operator performance monitoring and the feedback to Flight Crews and Appendix C deals with performance monitoring in general.

Due to the historical prevalence of different methodologies and metrics for measuring CCO and CDO performance across Europe, pan-European measurements have struggled with questions raised over comparing the performance at different airfields with misleading claims on performance based on different CDO definitions and metrics.

The European CCO / CDO Action Plan removes any such barrier to performance comparison by promoting harmonised definitions of CCO and CDO, as developed by the European CCO / CDO Task Force. This Plan does not aim to stop States reporting on locally agreed metrics but requests that when performance is measured on an international level or on the pan-European level, a consistent and harmonised definition and measurement of performance is undertaken – see Appendix B.

The Hawthorne Effect is a phenomenon in which the subjects of a study have been observed to alter their behaviour due to their awareness of being observed and has long been used to measure performance improvements. In the UK, NATS have used this phenomenon by publishing CDO statistics at UK airports with various degrees of granularity, even broken down to the ATC watch level or time of day. This performance monitoring has seen performance improvements of >20% in 10 years, albeit on CDO measured in a different way to that proposed in this Action Plan. The four London airports (EGLL, EGKK, EGSS & EGGW) have seen a rise in CDO achievement from 66% in 2000 to 90% in 2018.

In the UK, some airports have also taken the initiative to measure CDO performance by airline. In the London Heathrow Fly Quiet and Green (FQG) Campaign, CDO is one of seven metrics used to rank airlines according to their environmental performance. The league table considers all metrics and produces a final score, so airlines can see how they compare with other Heathrow operators. It also enables them to see how their performance has changed over time.

CDO figures are also reported through Flight Operations Performance Committees and sent to airlines who operate to and from Heathrow (for more information see Appendix Q4). In addition, through the UK Sustainable Aviation initiative, CDO figures are presented on a dashboard so further analysis can be made and then published for the airlines and Pilot communities. The publication of the London Heathrow CDO performance data is now widely accepted and has been credited with helping to foster a culture of continuous improvement among Flight Crews, ATCOs and airspace users.

The airline survey done to help develop the Action Plan clearly demonstrated that some airlines rely on the dissemination of CDO performance data from airports to measure their performance. The Task Force believes that all airports have a role in disseminating such performance information, where effort and data are available.

Performance measurements by airlines such as fuel benchmarking in the climb and descent phases, with associated individual Flight Crew performance feedback, gives incentives for Flight Crew to optimise their performance, and this has also been shown to improve overall airline performance – see Appendices L and Q6.

For national CCO / CDO performance monitoring, several stakeholders use different dashboards and charting possibilities to measure the performance. For example, NATS (UK) produces a multifunctional dashboard that can break down CDO performance by airport, airline, month, level band, year, aircraft type etc.

## LFV PERFORMANCE MEASUREMENT

LFV, the Swedish ANSP, uses time in level flight data to rank airline CDO performance. Unfiltered radar data is taken and processed to remove intersecting tracks (e.g. holding aircraft, round robin flights and missed approaches). The airlines can then be ranked in 'average time per level flight performance' with traffic light colours indicating the performance trend.

**Unfiltered radar data**

RANK	AIRLINE	[s]
1	NAX	43
2	IBK	46
3	BTI	48
4	KLM	56
5	NVR	57
6	AUI	60
7	BLX	64
8	NTJ	65
9	SAS	66
10	SWR	71
11	LOT	71
12	DLH	77
13	FIN	79
14	BAW	91
15	QTR	93
16	APF	97
17	THY	103
18	AFR	104
19	AUA	106
20	BER	108
21	EWG	118
22	VKG	129
23	AFL	130
24	PNX	162
25	DFL	329

**Remove self-intersecting tracks**

RANK	AIRLINE	[s]
1	0 NAX	34
2	0 IBK	36
3	0 BTI	40
4	0 KLM	48
5	1 AUI	56
6	3 SAS	56
7	-2 NVR	56
8	5 FIN	56
9	-1 NTJ	58
10	-3 BLX	61
11	0 LOT	62
12	-2 SWR	67
13	2 QTR	71
14	-2 DLH	75
15	-1 BAW	81
16	1 THY	86
17	-1 APF	87
18	1 AUA	96
19	4 AFL	98
20	-2 AFR	101
21	-1 BER	103
22	3 DFL	107
23	-2 EWG	111
24	-2 VKG	127
25	-1 PNX	151

**Adjust for airspace design and intensity**

RANK	AIRLINE	[s]
1	1 IBK	-28
2	1 BTI	-27
3	-2 NAX	-26
4	0 KLM	-13
5	0 AUI	-12
6	2 FIN	-12
7	-1 SAS	-6
8	-1 NVR	-3
9	2 LOT	0
10	0 BLX	1
11	-2 NTJ	3
12	1 QTR	5
13	-1 SWR	5
14	0 DLH	14
15	0 BAW	17
16	0 THY	21
17	0 APF	31
18	1 AFL	33
19	-1 AUA	36
20	0 AFR	40
21	0 BER	42
22	1 EWG	48
23	-1 DFL	50
24	0 VKG	67
25	0 PNX	78

Figure 19: LFV CDO performance measurements indicate ranking of airline CDO performance (for demonstration only)

The LFV example highlights how knowledge helps optimise CDO performance while also enabling the ANSP to identify best performers and those airlines to whom they may offer support to understand and improve their performance levels.

Performance measurement mechanisms like those detailed above all help to improve performance as the majority of operational ATCOs and Flight Crew have a natural desire to strive to perform better. However, the possibility of measuring individual performance may not be available to all stakeholders due to lack of data availability, effort or expertise.

The basic functionality of the performance dashboard will be monthly CDO figures from top of descent (CCO figures to top of climb) for the airport / airline selected, bearing in mind that performance comparisons between airlines may not be directly comparable due to e.g. time of operation (peak / non-peak etc.).

Enhanced functionalities could include the possibility to make more detailed performance comparisons e.g. to slice / aggregate by aircraft type, level band, time of analysis, performance through multiple sectors / centres or by country, alliance, type of flight etc.

The data source for these performance dashboard will be ADS-B surveillance data sourced from a commercial company. This will be combined with data from the Network Manager to ensure a robust performance measurement.

The basic functionality of the performance dashboard will be depicted in simple bar charts. Other more charting possibilities could be considered for the enhanced functionality (e.g. see Figure 20 for just one example).

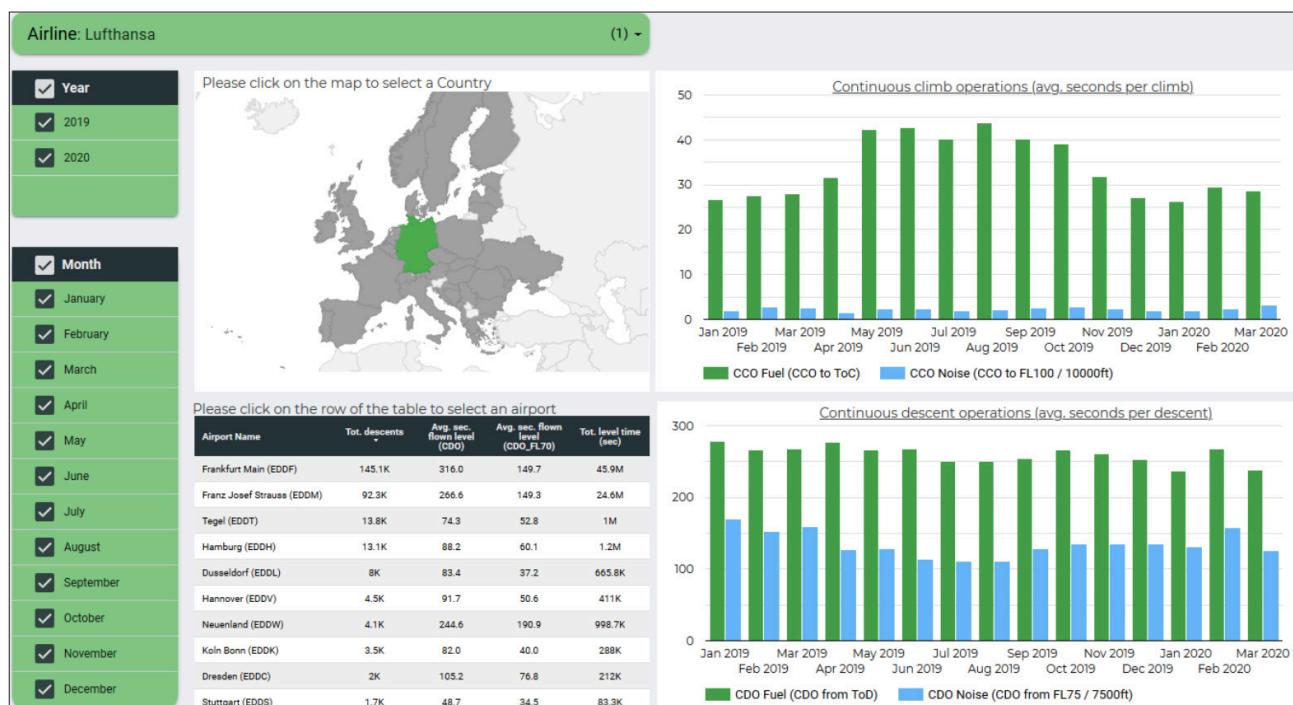


Figure 20: Example of a chart using enhanced functionalities of the proposed performance dashboard (test data)

It should be noted however that previous experiences have demonstrated that it is important to regularly check whether the desire to meet performance goals based on performance data is in line with overall CDO efficiency goals.

For example, when CDO was being trialled at EDDM, a CDO was recorded if the aircraft overflowed a specific waypoint. To improve performance measurement, it was recommended that radar vectors giving a shortcut should not be given in order to ensure that the waypoint was overflowed. As a result, this led to an overall increase in fuel burn, as the fuel savings from CDO were fewer than the extra fuel used to fly the extended trajectories. While this should not be an issue with the performance dashboard based on level segments, in general it is important to regularly check whether performance indicators are in line with performance goals.

Some stakeholders have developed innovative solutions to take local capacity issues into account when measuring CDO performance. For example, LFV has also developed a function that compares CDO performance (average time in level flight recorded per aircraft) with landing intensity and airspace design. Time in level flight is calculated per flight as a function of landing intensity; landing intensity is defined as the number of arrivals that arrival in a timeframe +/-10 minutes around the landing time of the flight in question.

Such functions can be created for distinct arrival flows, a performance assessment can then be carried out to see whether a flight performs better or worse than average, taking into account the interdependency with capacity at the airport level. If such an assessment could be extended to higher altitudes, it might be possible to somehow take the interdependency with airspace complexity into account. In Figure 21, the performance of individual flights can be compared to the average time in level flight expected under certain landing intensities.

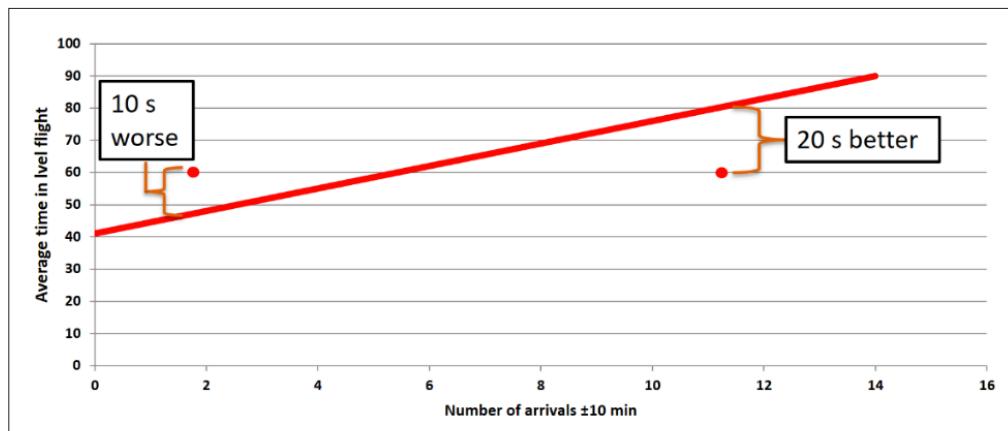


Figure 21: Developing a function to show the impact of traffic intensity and local capacity upon time in level flight (CDO) performance





## APPENDIX D: NOISE OPTIMISATION

### KEY MESSAGE

**A CDO from ToD will provide substantial fuel, emissions and economic benefits. At lower levels however, typically around airports, the primary environmental impact is noise.**

**CDOs have been demonstrated to provide noise level reductions of between 1-5dBA, typically at 8-25nm from the runway threshold, when compared to a non-CDO flight.**

While CDO operations have a great potential for reducing fuel consumption and emissions when operated from ToD or higher intermediate levels, at lower altitudes the primary environmental impact, especially at and around airports, is noise. This is nominally 7,000ft and below. Therefore, the mitigation of noise should also be prioritised whenever noise at and below 7,000ft is an issue at local level. In such cases, the noise CCO and noise CDO may be considered the optimum way of measuring CCO and CDO performance. It should be noted that if speed limits are below 230kts to separate a departure flow on the same routings, these flights will have to be flown partly with flaps extended, resulting in low climb rates and high noise levels.

It should however be noted that optimal climb profiles for noise reduction might be, at least for certain aircraft types, punishing in terms of additional fuel burn. It is therefore recommended that airlines carefully consider which Noise Abatement Departure Procedure (NADP) to fly as the different procedures may not actually reduce noise in the geographical location where it is required while also resulting in unwanted excess fuel burn.

In order to minimise the noise impact, it is important to understand how to support noise optimised approaches and the energy management of arriving aircraft, as well as the limits of how the performance can or cannot be monitored.

In addition to engine noise on arrival, aerodynamic noise is a significant contributor to the total noise emission of an aircraft depends strongly on airspeed.

The noise benefit of CDO varies on the altitude and duration of a level flight segment associated with flights not flying CDO. Further benefits can be gained when Flight Crews can design their approach paths on the low-energy side and, whenever possible, avoid using speed brakes or extending the landing gear early at low altitudes.

It is well understood that an undisturbed CDO decreases noise levels under the arrival route in areas that are located a few nautical miles beyond the final glide slope interception location. In these areas, noise mitigation can be up to 5 dB.<sup>23</sup>

Environmental regulations applied at airports usually refer to noise areas within, for example, Lden contours. The noise contours representing noise levels usually extend far beyond the point where aircraft join the glide path guidance of the final approach. For example, in cases where the vertical guidance of the final approach is intercepted around 2,000-4,000ft, the benefits can typically be reached within at 6 - 15nm from the runway threshold. At a majority of such airports, the CDO, if understood as a geometrically continuous descending profile, affects only the noise levels outside these noise areas.

In reality, the noise mitigation at some locations may be even greater, depending on the baseline operation that represents the benchmarking level. For instance, Finavia estimated that a long level flight segment at 2,000ft, related to independent

23- [www.sustainableaviation.co.uk](http://www.sustainableaviation.co.uk)

parallel operations as the benchmarking level, could result in a 15 dB difference compared to a well-optimised CDO profile. On the other hand, the noise mitigation potential may also be more limited as the long segment of level flight may have been introduced for safety reasons.

Noise can be further reduced by combining CDO with the Low Power / Low Drag method (LP/LD). This means that the lowest noise configuration for a given speed and altitude is flown during the approach, when more flaps are selected close to the minimum speed defined for the configuration and landing gear is extended as late as possible.

It should be emphasised that even aircraft with a geometrically optimised CDO profile, but with high speeds, early landing gear and early high lift device extensions and use of drag e.g. speed brakes, is far from noise optimised.

In cases where only the vertical flight path is being monitored, it must be noted that in high-energy situations apparent continuous descents may have been flown with excess drag, i.e. speed brakes out and with landing gear extended, when the arrival is far from noise optimal.

While efficient alternative means for monitoring CDO may be difficult to find, it is worth noting that requiring strict compliance with CDO vertical profiles may lead to situations where the arrivals are still not noise optimal. This is where the LP/LD procedures may be of particular benefit.

With LP/LD procedures, it is possible to reduce noise levels by approximately 2-5 dB in areas that are located approximately 3-10 nautical miles before the runway threshold. Under certain conditions, the area of reduced noise may even extend to the runway threshold. Again, the baseline operational conditions play a significant role in how much noise benefit can be achieved by LP/LD.

CDOs close to the ground should be flown preferably at low speed to avoid high drag devices for speed reduction. In a noise optimised CDO with LP/LD elements, the aircraft approaches the airport in a clean configuration which allows the aircraft to use either idle or low thrust settings with configuration to be deployed according to specific speeds.

The use of slower speeds usually makes it possible to delay the extension of the landing gear until a later moment during the approach. The scheduled speed profile should be such that the noise sensitive areas are overflowed with intermediate high lift device settings, without deployment of landing gear and spoilers, and with speeds towards the lower end of the configuration's specific speed window. Prior to glideslope interception however, configurations for maintaining speeds below 220kts can increase noise levels on the ground especially on long transitions in level flight.

From a performance-engineering point of view, LP/LD should be understood as a sum of net thrust and drag. This sum should be minimised over all locations of interest. When merging LP/LD with CDO it should be noted that, at the same time, the altitude should be as high as possible. An aircraft's drag is roughly a function of True Air Speed (TAS) to the power of two. In addition, the noise energy is roughly a function of TAS to the power of 5-7. These facts lead to the conclusion that, in a (noise optimised) combined CDO and LP/LD procedure, over approximately the last 15 nautical miles, the speeds should be slower than typically flown today by most of the operators.

In Figure 22 a comparison of the sound exposure levels of three different profiles is presented for the ground track under a typical narrow-body jet aircraft. The compared procedures are depicting:

1. A typical relatively high speed approach with 2000ft glide slope interception and early landing gear extension;
2. A CDO approach with high speed and early landing gear extension; and,
3. A good noise-optimised approach with CDO and LP/LD elements.

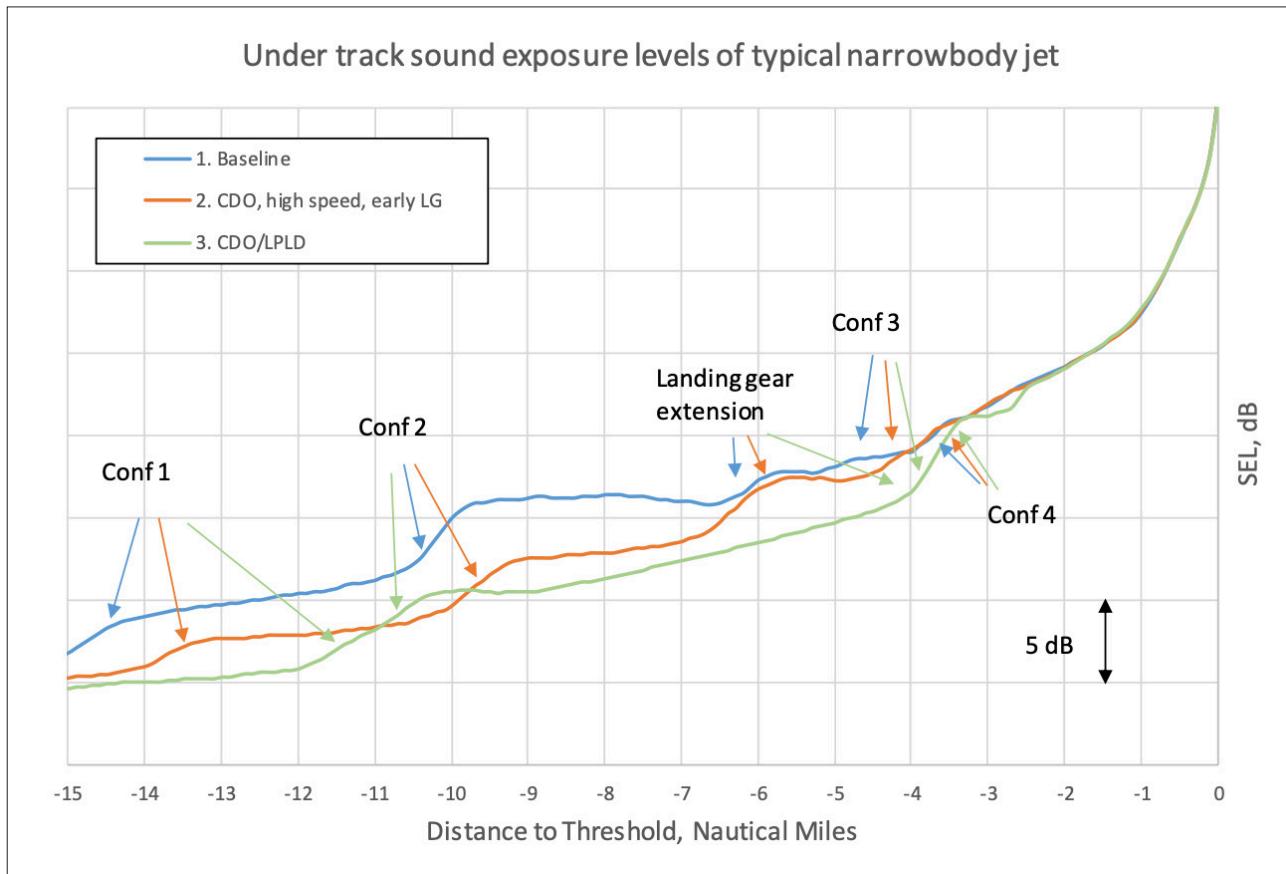


Figure 22: A comparison of three different approach profiles of a narrow-body jet under track sound exposure levels.

Figure 22 shows an approximate reduction of 3-5 dB in the well-optimised CDO LP/LD procedure when the baseline is the high speed, early landing gear, 2,000ft glide slope interception approach.

It should be noted that in the well noise-optimised CDO LP/LD procedure the intermediate configuration should be selected earlier than in comparative procedures. This is due to the relatively low noise profile of the intermediate high lift device configuration, and also due to the fact that in the intermediate configuration the aircraft is able to fly with slower speeds.

Most narrow-body jet aircraft also have a decreasing speed tendency in the intermediate configuration, without landing gear. Slower speed means lower aerodynamic noise and the possibility to delay landing gear extension. From an airport's noise capacity perspective, the reduction of 3 dB would mean that the number of operations could be doubled in order to reach the same noise exposure. However, for an extremely noise-optimised approach, the overall fuel consumption may be slightly higher than for a fuel use optimised profile.

Collaboration among airports, ANSPs and airlines is vital when the aim is to apply CDO and LP/LD procedures in everyday operations. In the beginning, it may be useful to primarily focus on their introduction during low traffic hours or at night. However, it may also be beneficial to look at applying changes during peak hours, as this is when noise improvements may have a strong impact on perceived noise levels and make for recognised noise improvement for the neighbours.



## APPENDIX E: AIP PUBLICATION

### KEY MESSAGE

An analysis undertaken by the European CCO / CDO Task Force revealed that current European AIPs contain a range of details on CDO availability at airports, ranging from detailed procedures to vague references.

The European CCO / CDO Task Force has agreed with stakeholders a recommendation for harmonised AIP material on CCO / CDO. The Task Force recommends a harmonised AIP location (ENR1.5 for high level content and AD2.21 / 2.22 for Airport specific content), structure and content. The content consists of a set of text proposals that are currently populated by existing good practice content but should be adapted to local procedures and conditions.

Information on the harmonised AIP material will be disseminated via ERNIP Part 1.

As part of its work programme, the European CCO / CDO Task Force made a review of the AIP content in Europe relating to CCO / CDO for the top 100 European airports (e.g. in sections AD, ENR1.5, GEN3.3, AIC). The results showed that:

- The AIPs of 41 airports contained information related to CDO
- Content related to CDO varied from detailed procedures to the mere mention of the word 'CDO' unrelated to any other content
- Good CDO AIP information was identified related to the following content:
  - amount of text
  - location of text
  - quality of text
  - references to information on chart
  - DTG
  - Phraseology
- Examples of poor AIP CDO content were also identified
- Only one airport had CCO information

The conclusion of this review was that the Task Force should propose harmonised AIP content related to CDO to ensure that identified good practices are shared and that Flight Crews / Flight Planners should always know where CCO- / CDO-related text may be found in an AIP. A harmonised structure that promotes the sharing of good AIP practices, phraseology, definitions, how CDO is measured etc. is needed.

The Task Force developed a proposal for the harmonised location, structure and content of CCO / CDO material in the AIP, based on current good practices that were identified in the European AIP review. This proposal was reviewed and agreed by various EUROCONTROL Working Arrangements such as the ATM Procedures Development Sub Group (APDSG) and Network Operations Team (NETOPS). These groups approved the Task Force's proposal to disseminate information on harmonised AIP content on CCO / CDO via ERNIP Part 1.

Detailed below are the agreed introductory texts to be added to ERNIP Part 1 to disseminate information about the harmonised AIP CCO / CDO material and the recommended AIP structure and content (together with text examples, based on existing AIP text) for harmonised AIP material on CCO / CDO.

**a) Introductory text to be added to ERNIP Part 1:**

CDOs are considered to be one of the main methods for reducing noise, fuel consumption and emissions, in compliance with the maintenance of current levels of air transport safety.

From the ANSP perspective, CDO can be facilitated through optimised airspace design combined with procedures, either published or applied tactically, that facilitate an idle descent, ideally from top of descent, removing inefficient intermediate level segments to the extent possible. ANSPs and Aerodrome Operators should ensure that information on CDO procedures at all airports under their responsibility should be promulgated in a harmonised format and structure in the AIP so that the Airspace Users and CFSPs are fully cognizant of where the information is located together with what type of content will be published.

The European CCO / CDO Task Force recommends a harmonised location, structure and content of CDO material in the AIP in order to provide ANSP's and Aerodrome Operators with guidance on where to publish, what content to publish and the requisite information for airspace users to enable the further implementation of Continuous Descent Operations (CDO) in airspace under their jurisdiction.

The Task Force recommends that:

- A high level text on the application of CDO and how CDO performance is measured taking into account the local CDO philosophy should be included in the ENR1.5 section of the AIP (5 - Holding, Approach and Departure Procedures); and,
- Focused tactical CDO information including specific local information such as phraseology, the timeframe of CDO availability, the ability to fly without the prescribed altitude or speed restrictions (due to low traffic situation) etc. should be included in the AD2.21 / 2.22 sections of the AIP (Noise Abatement Procedures) of individual airports. These sections should also detail any operational tactical procedures used by Controllers in the provision of ATC services that may be non-standard.

The following structure and content of AIP material relating to CCO / CDO is recommended. While the structure and AIP content headings are recommendations, it should be emphasised that the proposed example content has been copied / pasted from existing AIPs and should be considered to be an example with inclusion optional, depending on local needs and requirements. Numbers and figures are examples that can be tailored to specific ATM values.

### b) Recommended AIP structure and content:

**Note:** The following proposed content has been copied / pasted from existing AIPs and should be considered to be an example with inclusion optional, depending on local needs and requirements. Numbers and figures are examples that can be tailored to specific ATM values depending upon local conditions.

To be included in ENR1.5	
Heading	Example text
<b>CDO application</b>	<p><b>e.g. UKBB:</b> In accordance with appropriate ATC clearances, CDO can start from the TOD when an ACFT is cleared to a waypoint or via a combination of waypoints for direct routing/shortcut and the horizontal trajectory is defined up to and including the FAP. Thus, the exact distance to RWY is known and the descent profile can be readily calculated by the appropriate on board system (FMS) prior to start of the CDO.</p> <p>CDO is available on a published procedure basis / by being tactically applied / both.</p> <p><b>e.g. ENAV AIC6 2012:</b> In every airport, where operationally feasible, RNAV1 STARs will be published in order to facilitate CDO procedures. Where the publishing of CDO procedures is not available, CDO will be provided on a tactical basis wherever possible.</p> <p>Therefore, all aircraft are expected to fly a CDO profile to the extent possible. Compliance with CDO procedures is recommended provided they are compatible with ATC instructions and weather conditions are favourable.</p> <p>For more detailed information for each airport, see section 2.21 in the AD section of each aerodrome.</p>
<b>How CDO is measured</b>	<p><b>From CDO Task Force Harmonised metrics:</b> CDO is measured by the amount of time (seconds) spent in level flight from the top of descent to the FAF (for the fuel CDO) and from FL75 to the FAF (for the noise CDO) in accordance with the definitions of the European CCO / CDO Task Force. A descent will be deemed to have been continuously provided if no segment of level flight longer than 20 seconds occurs below FL75 - the start of the CDO measurement. 'Level flight' is interpreted as any segment of flight having a vertical speed less than 300 feet per minute, as recorded in the airport noise and track-keeping system. A single level segment of up to 30 seconds is allowed, if undertaken at a level immediately prior to glide slope intersection.</p>
<b>CCO / CDO specific routes</b>	Exact CCO / CDO routes under § ENR 3 ATS ROUTES (which is a collective of all ATS routes regardless of TYPE e.g. SID, STAR etc.)

Table 10: Recommended AIP structure (ENR1.5) for harmonised AIP material on CCO / CDO with example generic content

**Note:** The following proposed content has been copied / pasted from existing AIPs and should be considered to be an example with inclusion optional, depending on local needs and requirements. Numbers and figures are examples that can be tailored to specific ATM values depending on local conditions.

<b>To be included in AD 2.21 / 2.22:</b>	
<b>Heading</b>	<b>Example text</b>
<b>Availability of published STAR procedures</b>	<p>When the traffic situation permits and subject to ATC instructions, inbound aircraft are expected to fly a CDO profile during the hours of operation of each CDO arrival procedure to maintain as high an altitude as practical and adopt a low power, low drag, continuous descent approach profile.</p> <p>Outside of the published hours of operation and if the traffic situation allows, crews can ask specifically to perform CDO profiles and to maintain the speed as appropriate to facilitate the CDOs. This authorisation will be given whenever possible outside of those hours.</p> <p><b>e.g. EHAM</b> For RWY 06 and RWY 18R RNAV low-noise procedures, continuous descent approach (CDA), for jet aircraft will be used between 2130-0530 (2030-0430).</p> <p><b>e.g. LEBL</b> During night hours (from xxxx to xxxx), arrivals procedures in continuous descent (CDA) shall be authorised for noise abatement reasons.</p>
<b>Published CDO arrival Procedures</b>	<p><b>e.g. ENAV AIC:</b> All published STARs can potentially be flown with a CDO profile, because STARs have mainly "at or above" altitude restrictions not forcing the aircraft to fly steady segments or to cross fixes at specified altitudes. Specified minimum procedure altitudes must be adhered unless cancelled by ATC.</p> <p>The crew shall comply with speed and altitude restrictions published or provided for the destination airport, unless specifically amended by ATC.</p>
<b>CDO conditions</b>	<p><b>e.g. EBCI, UKBB:</b> CDO STARs are authorised only when the following conditions are respected (examples of restrictions that could be used):</p> <ul style="list-style-type: none"> <li>• ILS of RWY intended for landing is in operation;</li> <li>• No adverse weather conditions exist that may affect CDO (e.g. wind shear, thunderstorms, etc.);</li> <li>• No system degradations exist that may affect GNSS, DME/DME, or ILS operation;</li> <li>• Users which are approved for ICAO RNAV 1 navigation specification (or specific performance);</li> <li>• Runway Condition Code under XX;</li> <li>• Visibility exceeding 1900M;</li> <li>• Ceiling higher than X00FT above AD ELEV;</li> <li>• Cross wind component lower than 15KT (gusts included);</li> <li>• Tail wind component lower than 5KT (gusts included);</li> <li>• Non-compliance is allowed in case of precision approach CAT 2 AND 3; and,</li> <li>• No instrument or visual approach shall be made at angle less than the ILS glide path or less than 3 degree if no ILS is available.</li> </ul>

<b>Radar vectoring</b>	<p><b>e.g. EGBB, EFHK, EDDK, EGGW:</b></p> <p>As a portion of the procedure consists of vectoring, the specific distance to RWY threshold is not known to a Pilot prior to start of the CDO. In such cases, ATC will authorise the descent in compliance with the applicable radar vectoring minima. ATC will, as soon as practicable after first call, and as far as practicable prior to expected top of descent, provide the Pilot with an estimate of the flight track-miles to the RWY threshold (touchdown) as 'distance to go' (DTG) information, with regular range updates, if necessary. The Pilot will use this information to determine the optimum descent rate to achieve a CDO.</p> <p>Pilots who require additional track distance should inform ATC as soon as the requirement is apparent.</p> <p>If one or more intermediate levels are assigned due to radar vectoring minima, the Controller will inform the Pilot that he will be instructed as soon as practicable to further descend using following phraseology: EXPECT FURTHER DESCENT.</p> <p>In this way the Pilot will be made aware that the assigned level or altitude will be amended as soon as possible and then could perform a continuous descending profile.</p>
<b>Tactical CDO</b>	<p>Upon Pilot request and at ATC discretion, tactical CDO will be provided and facilitated by the use of appropriate phraseology and the provision of DTG upon first contact. DTG will be provided, wherever possible prior to the start of descent and should be requested from ATC if not provided upon first contact.</p>
<b>Speed restrictions</b>	<p><b>e.g. EGBB, EGKK:</b></p> <p>Speed restrictions depicted on the Aerodrome STAR charts are mandatory for applying standardised CDO approaches, optimising departure flow and for ATC separation purposes. In the event of a new (non-speed related) ATC Clearance being issued (e.g. an instruction to descend on ILS), Pilots are not absolved from a requirement to maintain a previously allocated speed.</p> <p>All speed restrictions are to be flown as accurately as possible. Thrust reductions should be achieved where possible by maintaining a 'clean' aircraft configuration and by landing with reduced flap. Aircraft shall use as final flap setting the minimum certified setting published in the aircraft-operating manual for the applicable conditions. However, each Pilot-in-Command may use a different flap setting approved for the aircraft if he determines that it is necessary in the interest of safety.</p> <p>In the interests of accurate spacing, Pilots are requested to comply with speed adjustments as promptly as feasible within their own operational constraints, advising ATC if circumstances necessitate a change of speed for aircraft performance reasons, and state what speeds will be used.</p>

<b>Expected speeds</b>	<p><b>e.g. EDDK:</b></p> <p>Unless otherwise advised by ATC, Pilots must plan the descent profile to comply with the speed and altitude restrictions depicted on the STARs. ATC may impose speed control if required for separation purposes. To facilitate CDO as much as possible, and in order to minimise tactical control or vectoring, unless ATC clears otherwise, aircraft should be flown:</p> <ul style="list-style-type: none"> <li>• 2XXkts as descent speed from cross over altitude. Advise ATC if higher descent speed is requested;</li> <li>• No faster than 250kts from the Speed Limiting Points and below FL 100;</li> <li>• 2XX - 2XXkts during the intermediate approach phase. Thereafter speed should be managed to achieve a continuous descent using as little power or drag as possible;</li> <li>• 1XXkts on base leg/closing heading to the ILS;</li> <li>• 1XX - 1XXkts when first established on the ILS;</li> <li>• 1XXkts between 7 and 4 DME;</li> <li>• Extend gear 2000ft GND or later; and,</li> <li>• Speed shall not be reduced below 1XXkts until reaching X nm to threshold.</li> </ul> <p>Aircraft with a cruising IAS below those indicated above, shall maintain cruising speed up to the adjustment point concerned. ATC shall be informed of the speeds that may be maintained, if unable to comply with the speed adjustments above.</p>
<b>Phraseology</b>	<p><b>e.g. EBBR, UKBB:</b></p> <p>To stress the possibility to perform CDO and to avoid to provide descent clearance much in advance with respect to the optimum descent profile, ATCOs at XXXX will use the following phraseology: "WHEN READY DESCEND TO (level)".</p> <p>After clearance "WHEN READY DESCEND TO (level)" Pilot should maintain the cruising/last assigned level until the optimal descent point/TOD that is determined by Pilot or FMS, then start descent with no extra requests unless other ATC instructions are issued.</p> <p>When authorising the published CDO procedures, ATC will use the following phraseology: WHEN READY DESCEND VIA (designator STAR) ARRIVAL to (level).</p> <p>When DTG information is passed together with descent clearance, the following phraseology will be used: "(Number) TRACK MILES FROM TOUCHDOWN, WHEN READY DESCEND TO (level)".</p>

Table 11: Recommended AIP structure (AD2.21 / 2.22) for harmonised AIP material on CCO / CDO with example generic content

For more phraseology examples, see Appendix M.





## APPENDIX F: AIRSPACE / PROCEDURE DESIGN

### KEY MESSAGE

**CCO and CDO should be considered as an integral part of the airspace design process as detailed in ERNIP Part 1. Where possible, CCO and CDO should be enabled to ToC / from ToD or to / from as high a level as possible.**

**It is recognised that flying a well-designed published procedure is an enabler for CDO by increasing the predictability (accurate DTG) for both Flight Crew and ATCOs. Individual airspace solutions will depend upon local constraints, topography and traffic conditions.**

The European CCO / CDO Action Plan promotes CCO and CDO as being an integral part of the airspace design process and as such has proposed several text updates to the European Route Network Improvement Plan or ERNIP Part 1.

### ERNIP Part 1 updates

These updates focus along the following proposals:

- CCO / CDO optimisation should be considered as an integral part of the airspace change process;
- CCO and CDO should be enabled to / from as high a level as possible (depending upon local conditions);
- Emphasising the importance of the environmental assessment in the airspace change process;
- Emphasising that external environmental experts should be involved in the airspace change process;
- Emphasising that Aircraft Operators should be involved in the airspace change process;
- Introducing 'good practice' principles of airspace and procedure design to enable more optimised CCO and CDO; and,
- Detailing the pros and cons of various arrival procedures to enable CDO in different operational environments.

The European CCO / CDO Task Force is looking to work with stakeholders on their airspace design process to ensure that CCO- and CDO-enabling principles are incorporated into the airspace design process. As such, the Task Force has developed a set of 'best practice' principles for airspace design:

- Best practice airspace design principles should be detailed in guidance provided by ERNIP and be used in all airspace change projects;
- LoAs, where required / needed / in place, should enable optimal descent profiles (ideally from Top of Descent) and where operational benefits may be enabled, be designed on a flexible basis that can be adapted to runway direction, high / low demand periods, seasonal traffic, week / weekend traffic patterns and should be regularly reviewed on an individual restriction basis;
- LoAs may benefit from the creation of new waypoints to enable a new, more optimal and higher Top of Descent point, or a more optimum descent profile. Such changes should be promoted during the regular LoA reviews;
- Where altitude restrictions exist that are not directly related to a waypoint, consideration should be given to creating a respective waypoint / restriction so that they are brought to the attention of airspace users and / or CFSPs. This allows

consideration by CFSPs for fuel planning and by the FMS for optimised flight paths that are correlated with practical daily use;

- Airspace design should include the design of arrival and departure routes together - simulations evaluating the effect of random variations of input variables are useful in evaluating likely trajectories and can therefore be used to optimise crossing points / levels as well as the trade-offs between various choices based on specific cases and locations. Where level flight is required for crossing tracks, this should be as high as practicable;
- Arrival routes should follow the optimum idle descent path of the most common aircraft profiles for each individual runway bearing in mind aircraft weights, prevalent winds, temperatures, speed schedules and optimum descent angles etc. Rules of thumb are available for supporting descent route creation. Aircraft Operators should be specifically requested to support this descent route creation;
- Optimum profile calculators may be used during airspace design to indicate minimum / maximum average FLs over certain waypoints based on the descent profiles of different aircraft types;
- There is a need to be flexible when designing an arrival route - airspace design usually takes into account a workable solution for traffic. When possible, profiles should also be optimised for non-peak periods. Alternatively, dedicated procedures can be developed for non-peak periods;
- When such peak / non-peak periods are determinable, solutions may be found to make optimised descent profiles available during specific times / days / seasons or under specified conditions; and,
- The FMS logic of all Manufacturers should be taken into account when creating altitude windows in arrival routes - some FMSs may delete 'unnecessary constraints above, at and even below CFL'. This is because any constraints above the cruising level are deleted while the upper limit of a constraint window will also be deleted if it is located above the cruising level. Aircraft Operators can reinforce the understanding of this point through education / training of the Flight Crew.

As a rule, the number of constraints should be minimised. If constraints exist, these points should be emphasised: based on the Task Force members' experience, a basic set of "common sense" recommendations has been proposed for airspace design:

- Routes should be designed with a minimum number of constraints; having a large number of constraints limits the potential for the flight to optimise its climb and descent profile, and also increases the rate of non-compliance;
- Constraints that are very close to each other (e.g. a minimum of 10nm) should be avoided, as some FMSs may be unable to handle them;
- When speed constraints along a STAR are needed, it is preferable to define an entry speed into the STAR (e.g. "Maintain last MACH number, 280kts on transition") than to have multiple constraints along the STAR (in practice however, such remarks may be overlooked by Flight Crews);
- Speed constraints should be avoided in the FL110-FL090 level band, because most FMSs have a pre-programmed descent speed limit of 250kts below FL100, which would overrule a waypoint constraint (which would have lower FMS priority);
- Transfer altitude conditions between sectors or between ACCs (LoAs) should be implemented by having a waypoint altitude constraint in the SID or STAR, in order to help CFSPs with flight planning;
- If altitude waypoint constraints are required, the preference is to use:
  - 1) whenever possible, "at or above" constraints;
  - 2) "at or below" constraints;
  - 3) "between constraints" (altitude window); and then,
  - 4) "at" constraints.

- When designing arrival routes, it is recommended that airline requirements and policies to reduce the descent rate within the last 2,000ft to 1,500ft/min and within the last 1000ft to 1000ft/min are taken into consideration. To reflect the transfer altitude of LoAs between sectors it is also recommended that a respective waypoint altitude constraint be created to also help CFSPs with flight planning.

Depending on the local needs, different airspace design solutions can be implemented to support CDO operations. The subsections below describe the different benefits and good practices of each solution for Closed Path, Open Path, Tailored Arrivals (TA) or Point Merge. They do not guarantee perfect CDO but they support CDO optimisation.

For future implementations into large hub airports, a 3D airspace tube could be considered, one which is controlled by one ATC unit from ToD until the end of the CDO procedure or from the start of the CCO procedure until ToC. Such a concept would have to address the delegation of ATS provision if the tube crossed lateral / vertical boundaries between neighbouring ANSPs.

This appendix contains extracts from ERNIP Part 1 together with complementary text and case studies of actual implementations of different airspace design methods. It is not proposed to replace the existing text in ERNIP Part 1.

### Closed Path design

Optimised Descent Profiles can only be flown if the exact distance to touchdown is given, either by adhering to a fixed STAR or by receiving this information from ATC. A Closed STAR procedure provides the Flight Crew with a defined distance to touchdown. The ideal Closed Path design is one with the minimum amount of distance flown, with no speed or altitude restrictions so that each aircraft can fly its optimum descent profile. Closed STAR procedures can be published in the AIP and can therefore be pre-programmed into the FMS.

Where multiple arrival routes are operated onto a single runway using Closed STARs, a strategic and tactical sequence of aircraft is required to ensure that safety is maintained in the case of aircraft automatically making a final approach turn into the direction of other arriving aircraft on different routes.

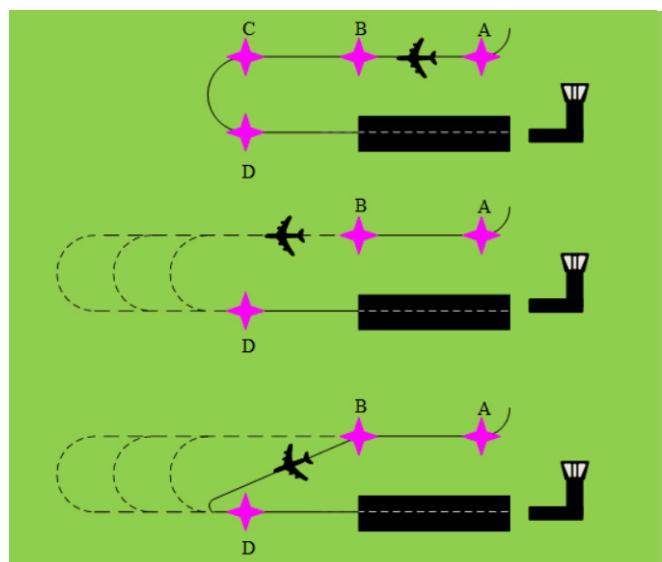


Figure 23: Closed (top), Open (centre) and Open with a shortcut (bottom) STAR designs

In Figure 23, the Closed STAR procedure goes via waypoints A-B-C-D to the runway. Waypoint D represents the start of the final approach segment. In a Closed STAR procedure design, the FMS is able to monitor the total energy of the aircraft versus the planned trajectory to the greatest extent possible. With a Closed STAR procedure, if an aircraft is cleared by ATC for a shorter route after passing ToD (e.g. via waypoints A-B-D instead of A-B-C-D), this will result in the aircraft having too much

energy relative to landing requirements. The corresponding reduction in energy is achieved by using various drag devices, such as speed brakes or premature reconfiguration of the aircraft through slats / flaps or extension of the retractable landing gear. This may result in more noise on the ground.

Closed STAR procedures however, can be designed and published to anticipate alternative routeing to be given by ATC on a tactical basis. These tactical changes may be facilitated by providing additional waypoints allowing ATC to provide path stretching or reduction by the using instructions such as 'direct to a waypoint'. However, these tactical changes, needed to maximise runway capacity, may affect the vertical profile planned by the area navigation system.

When tactical changes are given by ATC, the Controllers should also give regular and accurate DTG information to the Flight Crew. This is essential in order to allow the Flight Crew to optimise the descent profile.

In order to improve predictability, published descent procedures should be very close to what is actually flown and should be followed by both ATCOs and Flight Crews. They should also not be cancelled on a regular basis.

## THE ENAV CASE

The following example from ENAV demonstrates how the 'trombone' concept, designed with a closed STAR structure, has been successfully implemented since 2017 at Rome Fiumicino Airport (LIRF).

At LIRF, the RNAV1 STARs (Trombones) are:

- Designed with a Closed Path structure: the trombones standardise the downwind-base-final circuit;
- Both trombones serve both runways to enhance maximum flexibility (ATCO side), and horizontal path efficiency (AU side); Arrival routes design coupled with on-board technical capabilities enable the operational management of the arrival traffic with the use of the 'direct to' technique by ATCOs;
- Approach management with radar vectors is used only occasionally;
- Trombone arrival routes are coded in the FMS database thus enabling high predictability and constant availability of DTG;
- With the use of the 'direct to' technique, paths can be shortened inside the structure; and,
- The paths can be changed with the 'direct to' technique provided that the angle of turn when intercepting the remainder of the planned trajectory does not exceed 90°, as illustrated in Figure 24.

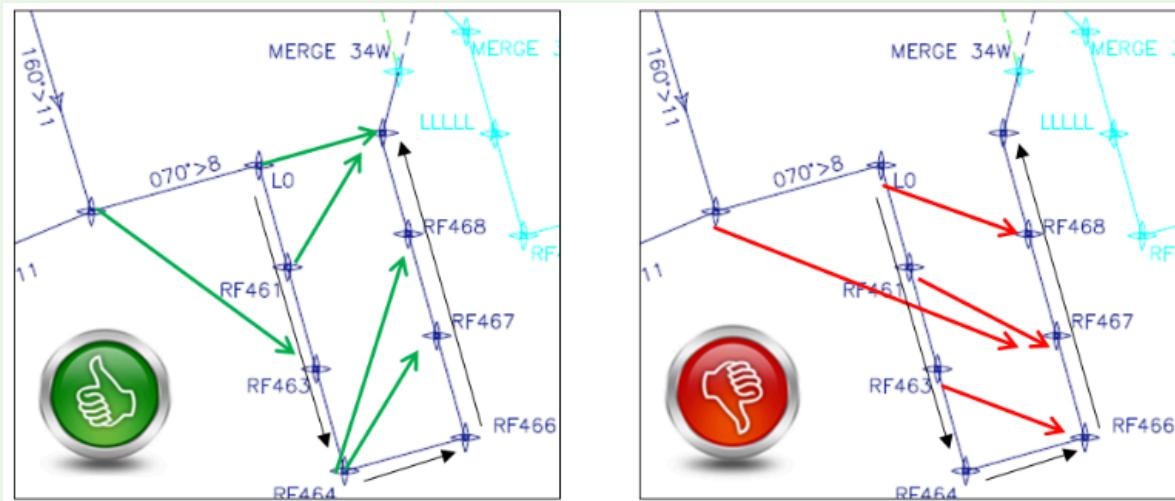


Figure 24: 'Direct to' technique used at Rome Fiumicino Airport.

The new STARs were deployed following a collaborative process, including cross-training, joint meetings and cockpit flights carried out by ATCOs. For the initial design, altitude and speed constraints were removed where possible. Following the continuous collaborative process, the airlines identified that more published speed / level constraints were required for better energy and profile management. Altitude level 'windows' were then identified instead of fixed altitude level constraints.

This concept enables CDO to be integrated in the RNAV1 'Trombone' procedures while the dedicated arrival segments established to fly the transition from Free Route Airspace, allow the optimisation of the vertical profile and guarantee to airspace users a high degree of predictability during the whole approach phase.

### Tailored Approaches design

The "tailored approaches" (TA) concept has been designed to take advantage of the capabilities widely available on today's aircraft, among them flight management computers and integrated data link systems.

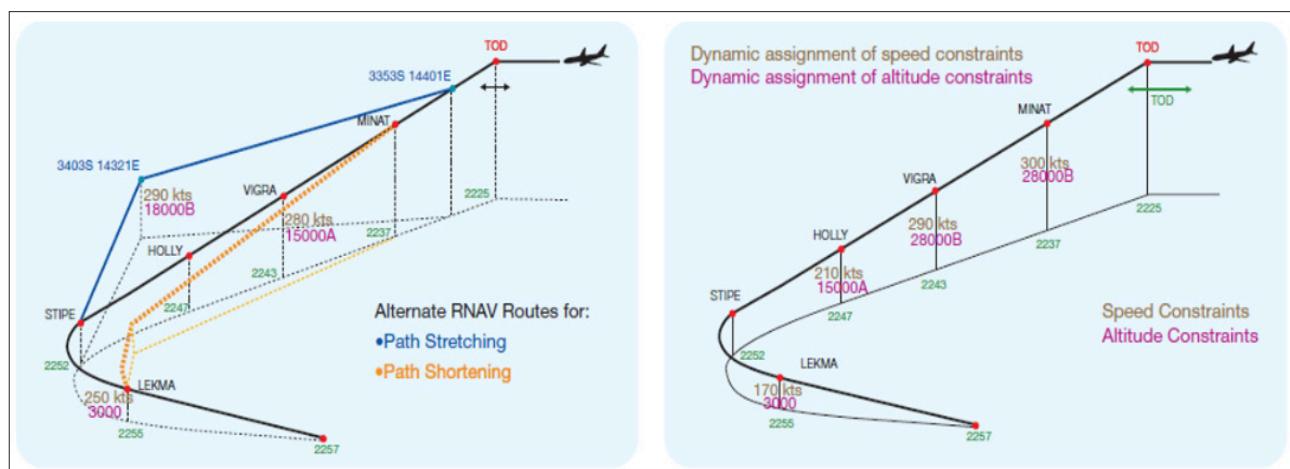


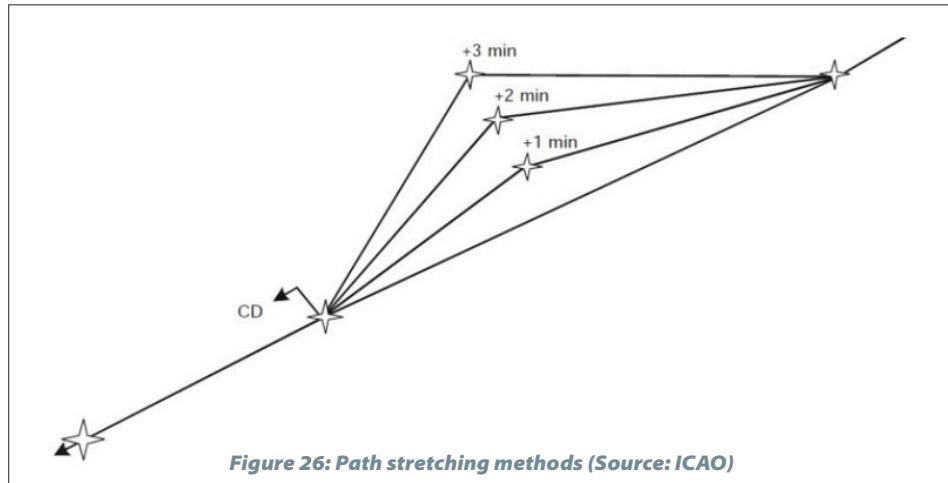
Figure 25: The Tailored Arrivals concept (from ICAO)

The ideal TA is a trajectory that allows the aircraft to meet the required time at the metering fix (if any) while carrying out an idle descent along the optimal lateral path. The TA concept uses speed and altitude control to adjust the timing and descent profile of an aircraft.

Therefore, the publishing of STARs' level and speed windows should have aircraft performance limits and the wind data available to Flight Crews taken into consideration. It is also advisable to reduce the number of waypoints so as to heighten compliance with lateral and vertical constraints. Simulations could help the procedure designer assess the effect of different variables on the TA.

With this airspace design solution, in low peak periods, the same Closed TA STAR can be used together with the tactical facilitation made by the Controller so that no speed or altitude restrictions apply, allowing the crew to fly the most optimal profile.

If tactical intervention is still expected in peak hours, the use of path stretching (see Figure 26) in the design phase is the preferred option. This gives the Controller several "paths" to sequence airplanes and the crew can still adapt the expected distance to go before descent is initiated.



Note that this solution requires more airspace volume than other solutions and may not be practicable in European TMAs where such space may not be available.

### Open Path design

At airports where the Closed Path or tailored approaches options are not possible, or where the most appropriate solution is Open Path STARs, they provide track guidance to a downwind track position from which the aircraft is tactically guided by ATC to intercept the final approach track. Alternatively, the Open Path procedure may terminate at the entry of a TMA sector or at the merge point of two flows. In this latter case, because it is geographically further away from the runway, this gives ATC more freedom to vector aircraft. This can prove beneficial in cases where the runway configuration changes frequently. Radar-vectorized Open STARs give greater flexibility in maintaining a high runway throughput, which is typically required in high-density traffic environments. Although they provide more ATC capacity than Closed Path STARs, they also require more tactical ATC interventions.

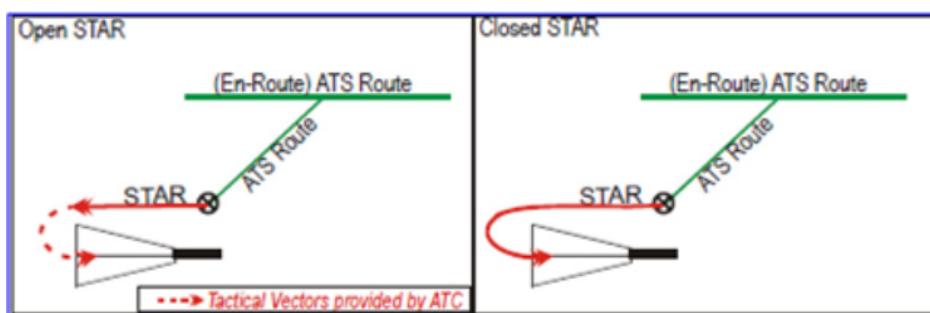


Figure 27: Closed versus Open STARs

The FMS assumes that the trajectory to be flown will be almost direct from the intermediate approach fix to the RWY i.e. the FMS does not know what path stretching will be applied by ATC and assumes that distance to touchdown is much shorter than is actually the case. In this case, the vertical profile in the FMS will reflect the assumed lateral trajectory (resulting in a non-optimised vertical profile) unless the Flight Crew generates their own FMS inputs to reflect the predicted trajectory that is expected to be flown, or uses the flight management modes so as to avoid a level segment.

Therefore, with Open STARs, ATC should facilitate an optimised vertical profile by providing regular and accurate DTG information to the Flight Crew, wherever possible, so that a descent profile without inefficient level segments can be executed to the extent possible. Even with no level segments, the Open path option will create a non-optimal descent unless the distance to go information is given before the descent is initiated. This is the main reason why, from a CDO perspective, Closed Path procedures are preferable to Open Path ones.

## ANA-LUX CASE

One example of CDO procedures based on an Open STAR has been implemented by ANA-Lux. ANA-Lux, the Luxembourgian ANSP, has designed CDO procedures based on initial vectoring followed by direct routing to published waypoints that are explicitly referred in the CDO ATC clearance, as illustrated in Figure 28.

In this example, the following ATC clearance will be given:

"LGL932 cleared CDO ILS approach RWY24 via [significant point] (e.g. "CONDO") QNH 1021, report established".

The Flight Crew will read back:

"Cleared CDO ILS approach RWY24 via CONDO. QNH 1021, LGL932"

CDO are still flown via Open stars based on vectoring but the ATCO does not need to provide DTG information as the concept allows the Flight Crew to know the flight distance between the published waypoints once cleared to the initial waypoint.

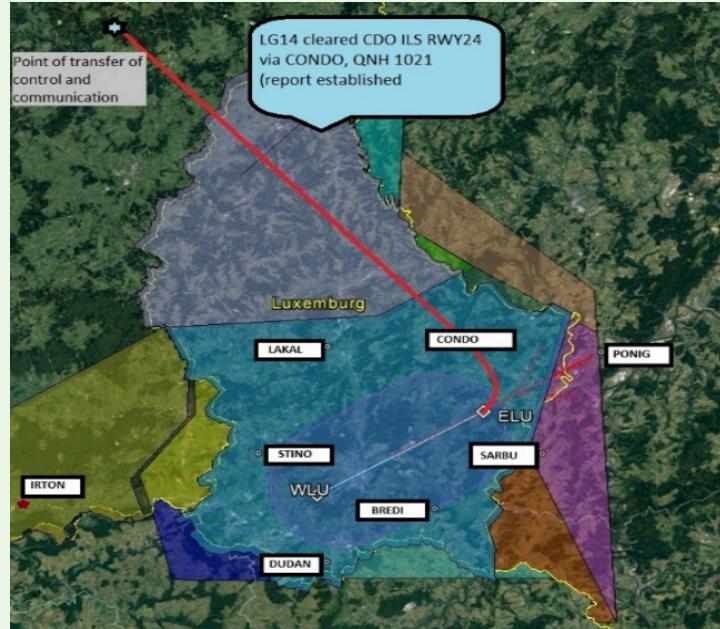


Figure 28: Vectoring followed by direct routing to IAPs at Luxembourg (ELLX)

## Point Merge

The Point Merge System (PMS) is a systemised method for sequencing arrival flows, designed to work in high traffic loads without radar vectoring. It is based on a specific RNAV1 route structure, consisting of a waypoint (the merge point) and pre-defined legs (the sequencing legs) equidistant from this point. The sequencing is achieved with a "direct-to" instruction to the merge point at the appropriate time. The legs are only used to delay aircraft when necessary ("path stretching"); the length of the legs reflects the required delay absorption capacity. This system enhances situational awareness and reduces workload for Flight Crews and ATCOs.

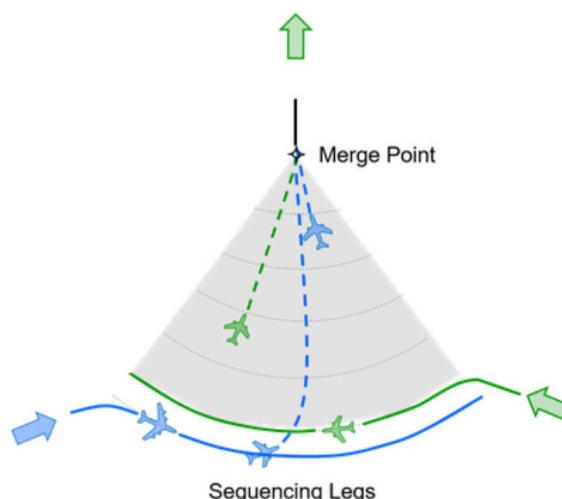


Figure 29: Point Merge System

In nominal conditions, aircraft remain on lateral navigation at all times. In low traffic conditions, aircraft are cleared direct to the merge point and DTG will be known by the FMS. In higher traffic conditions with aircraft flying along the sequencing legs, there will be vertical restrictions (level-offs in case of parallel legs) until the “direct to” instruction at which point the DTG is known as well. CDO may also be enabled by designing the procedure with an altitude restriction of ‘at or above’ at the beginning of the arc, depending upon the geometry of the sequencing legs.

## POINT MERGE – THE EIDW (DUBLIN, IRELAND) CASE

Point Merge facilitates a dynamic and flexible management of arrivals and enables a maximum number of arrivals to be sequenced with minimum spacing towards the arrival runway. In light to moderate traffic conditions it facilitates “straight in approaches” and where necessary some following of the sequencing legs as shown in Figure 30a below. Any interruption of descent will be negligible in such situations (e.g. less than two minutes).

Lateral holding in a Point Merge System, is typically followed by a direct routing to the Merge Point, which is then followed by a Closed Path route, giving an accurate remaining distance after leaving the sequencing leg(s). Figure 30b shows extensive use of the Point Merge legs with almost no racetrack pattern holding, whereas Figure 30c shows a situation where the Point Merge capacity has been fully exploited and significant racetrack holding is also required. The latter situations usually occur because of a reduction in the runway arrival rate; and other strategies such as ATFM arrival regulations will be required, to avoid ATC overload, and to minimise the environmental impact. It should be stressed that the EIDW PMS system was designed prior to a significant traffic increase (+40%) after the deployment of Point Merge that was not taken into account in the design. The situation shown in Figure 30c should not therefore be taken as a regular occurrence and in this particular example, will likely be alleviated by the second runway now under construction.

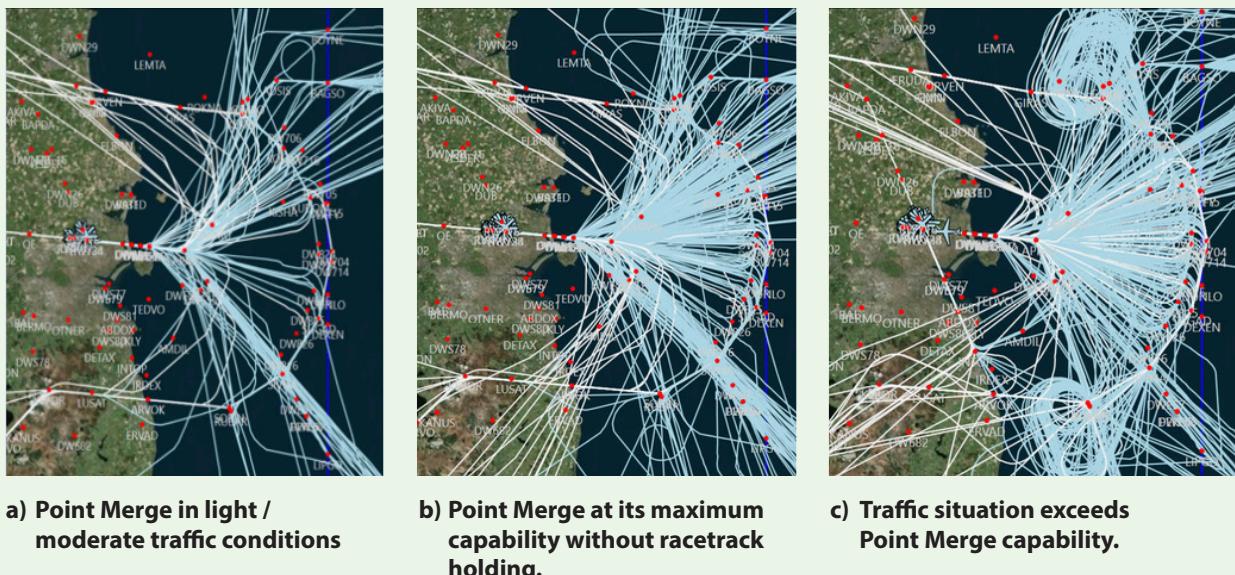


Figure 30: Point Merge System at EIDW under different traffic conditions

Whereas it is acknowledged that holding and Point Merge legs have less environmental impact when they take place at higher altitudes, the geographical location of the Point Merge legs is also important. In the examples above, the noise impact is minimal as the Point Merge legs are over the sea. Similar benefits may be found where the Point Merge legs are over land, away from areas of dense population. Where Point Merge legs are over land, the PMS design will tend to have higher sequencing legs and merge point above 6,000ft above terrain whenever possible, so that noise considerations should generally only be concerned with the last segment(s) before joining final.

One advantage of Point Merge over racetrack holding is that the aircraft is always "configured" for an immediate approach from any physical location on the sequencing arc. There is no necessity to complete a racetrack pattern (e.g. the aircraft in a racetrack pattern can be heading in the opposite direction to that of the runway).

Figure 31 illustrates typical arrival vertical profiles in a Point Merge system.

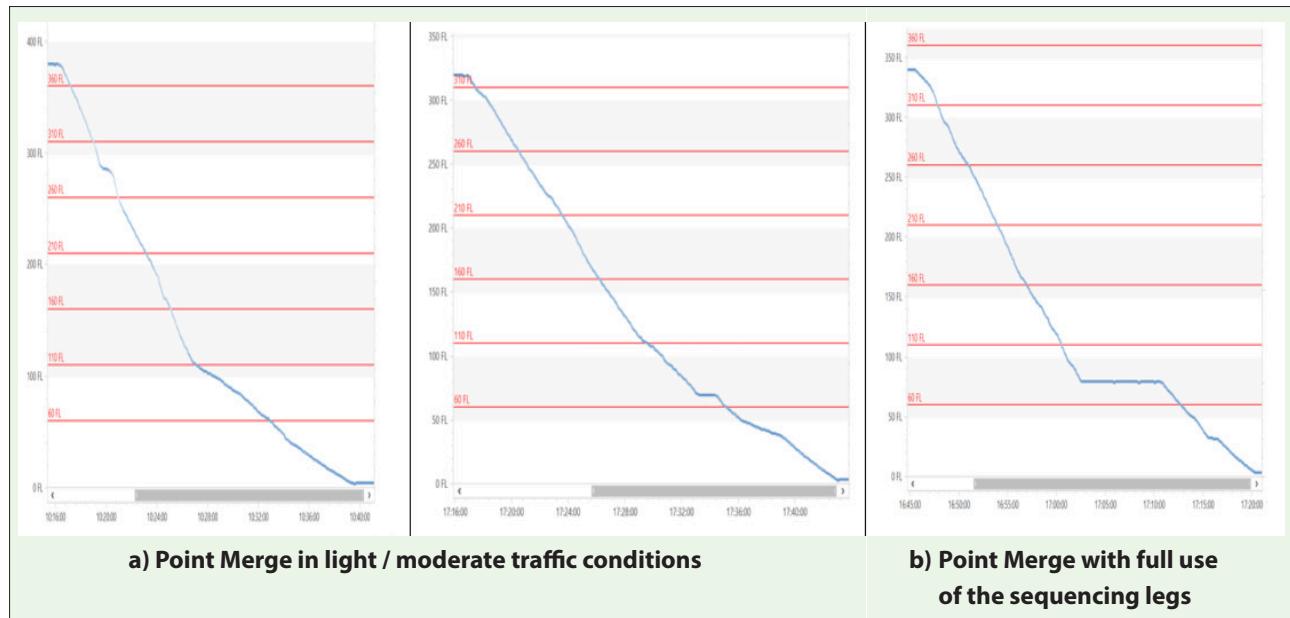


Figure 31: Typical arrival profiles in a Point Merge System

At a higher level, SESAR is carrying out studies that could support airspace design solutions in the future. For example, SESAR solution 62 "P-RNAV in complex TMA" provides a catalogue of structures that may alleviate the need for racetrack holding patterns. There are primarily two types of structures: trombones and Point Merge structures. In both cases, a path extension still exists, but it is more predictable for the Flight Crew than racetrack holding. In addition, the structures provide successive aircraft with lateral separation at an earlier stage than racetrack holding patterns, thereby making it unnecessary for ATC to provide vertical separation, which results in fewer restrictions in the descent.

There are examples, though, of when holding cannot be alleviated and should still be used in the case when downstream airspace capacity is no longer sufficient to accommodate inbound traffic e.g. in case of runway closure, or weather.

In the EIDW example, the ATCOs were able to delay the use / opening of the holds because the new Point Merge environment provided a clearer structured traffic picture, when compared to the old 'vectoring' environment.

SESR solution 11, "CDO Using Point Merge", provides an alternative to Point Merge structures. Here, aircraft are vectored until they can be cleared direct to the merge point ('Merge to Point' procedures), while vectoring is moved further away from the airport, and all aircraft follow a repeatable flight path after they pass the merge point.

SESR solutions 62 and 11 are complemented by the more advanced solution 51 "Enhanced terminal operations with RNP transition to LPV (Localiser Performance with Vertical guidance)", and solution 9 "Enhanced terminal operations with automatic RNP transition to ILS / GLS". These solutions both enable a seamless transition from these airspace structures into the final approach path.



## APPENDIX G: LoAS / RAD RESTRICTIONS

### **KEY MESSAGE**

**The conclusions of several projects have shown that LoAs or transfer of control points may not always be conducive to facilitating an optimal vertical profile.**

**The European CCO / CDO Action Plan promotes a regular and systematic collaborative LoA review process. This process should review all individual restrictions that are included in each LoA to identify whether they are still relevant or may need to be updated due to a change of route / sector boundary, current fleet mix on the route or the performance envelope of newer aircraft. The aim of this review is to minimise, to the minimum time possible, the vertical inefficiency in the transfer of air traffic between ATS units.**

**New LoAs should be designed on a flexible basis that can be adapted to runway direction, high / low demand periods, seasonal traffic, week / weekend traffic patterns, where possible. LoAs should also be reviewed on a regular basis and may also benefit from the creation of new waypoints to enable a new, more optimal and higher Top of Descent point, or a more optimum descent profile.**

The purpose of an LoA is to define the coordination procedures to be applied between ATS units when transferring air traffic between ATC sectors and centres. It allows Controllers to safely manage the high level of traffic in European airspace by providing traffic flow separation.

However, LoAs, can in some cases, be too static and somewhat conservative. The objective is rather to create greater flexibility in the system by adapting LoA restrictions to flight efficiency profiles, so increasing fuel saving and noise abatement.

The European CCO / CDO Task Force analysed the level segments found during climb and descent at multiple major and minor airports across Europe and discovered that, in general, most segments of inefficient intermediate level flight are found at higher levels because the aircrafts were complying with LoA level restrictions.

In addition, the conclusions of several projects (e.g. the SESAR ODP Project) have shown that LoAs or transfer of control points may not always facilitate an optimal vertical profile. While the transfer of control points and level restrictions are likely to be defined for ATFM reasons, to de-conflict traffic flows and maintain capacity in adjacent sectors, they can still be optimised. Therefore, while some flexibility can be given in terms of the altitude of the transfer of control via ATC tactical clearances, this may have a negative impact on predictability.

The SESAR ODP Project concluded that LoAs related to specific waypoints could be moved, to newly created more optimally located waypoints, while reviews could be regularly undertaken to update the existing transfer of control levels by comparing the effect that the performance envelope of more modern aircraft types or the profiles of more modern fleet mixes would have upon inefficiency.

The European CCO / CDO Action Plan promotes a regular and systematic collaborative LoA review process. This process should review all the individual restrictions that have been used to develop each LoA in a step by step process. It should identify whether they are still relevant or if they need to be updated due to a change of route / sector boundary, current fleet mix on the route or the performance envelope of newer aircraft.

The aim of this review is to minimise, the amount of time spent in level flight between airspace sectors and to ensure that

the LoAs do not unfairly restrict arriving / departing traffic with unnecessary vertical constraints that result in inefficient levels-offs and corresponding increases in fuel penalties and associated emissions. Where possible, in mutual agreements between ATC units, ANSPs should declare FL restrictions on LoAs, as "non-permanent" or "on request".

For new (and existing) LoAs, they should be designed to facilitate optimal descent profiles (ideally from ToD). The Action Plan also requests that the appropriate stakeholders to design LoAs on a more flexible basis; one that can be adapted to runway direction, high / low demand periods, seasonal traffic, week / weekend traffic patterns, where possible. LoAs should also be reviewed on a regular basis and operations may also benefit from the creation of new waypoints to enable a new, more optimal and higher Top of Descent point, or a more optimum descent profile.

ANSPs should also consider applying transfer conditions not necessarily "at level" but "descending / climbing" out of a specific altitude / FL. Extra benefits to flight efficiency are granted by LoAs that can be triggered "on request", rather than on a permanent application basis.

Where LoAs exist, CCOs and CDOs can be disrupted by a late handover from one ATCO to the next. Changing frequency, checking in and getting a new level clearance can take over a minute. High performance modern jets can climb and descend at rates in excess of 3,000ft/min. In a 'no conflict' situation, a handover initiated at only a short time before the cleared level, can result in an inefficient level-off, in a no conflict situation, disrupting the CCO / CDO and increasing Flight Crew workload. Finally, where altitude restrictions exist due to LoAs (standing agreements) between centres / sectors, consideration should be given to creating a respective waypoint / restriction so that the level restrictions are brought to the attention of airspace users and / or CFSPs. This allows consideration by CFSPs for fuel planning and by the FMS for optimised flight paths that are correlated with practical daily use.

This set of measures can guarantee safe and efficient operational management by ATCOs together with a significant reduction of inefficient level-offs.

The RAD allows States / FABs / ANSPs to maximise capacity and reduce complexity by defining restrictions that prevent disruption to the organised system of major traffic flows through congested areas with due regard to Aircraft Operators' requirements.

The RAD also contributes, however, to reducing vertical flight efficiency due to many altitude restrictions that may lead to reduced CDO performances, especially from ToD. Optimising CDO from ToD or higher levels from the flight planning point of view, requires that LoAs, RAD restrictions and / or internal working methods be regularly and collaboratively reviewed. This requires the support of the operational stakeholders involved, the Network Manager included, to ensure that all inter-dependencies (mainly capacity) are preserved.

Regardless of the measures outlined above, it should be noted that under certain circumstances, trajectory predictability is an inherent part of the system in maintaining capacity. The objective of the NM "file it, fly it" campaign is to make sure that this level of predictability is maintained in the summer period.

Bearing this in mind, ATCOs, ATFM Staff and NM should be encouraged, wherever possible and when the traffic situation permits, to relax RAD restrictions on a tactical basis. This allows aircraft to remain at more optimum (higher) flight levels for longer, and to waive vertical constraints so as to facilitate enhanced performance.

This enables the Flight Crew to further optimise the descent profile and may allow for tactical handovers to neighbouring sectors at more optimum levels than usual.

Coordination with neighbouring / downstream sectors may be required to ensure that any such relaxation of RAD restrictions will not unduly influence sector sequences or create overload situations in sectors handling the remaining trajectory of the flight concerned.

As part of its work programme, the CCO / CDO task Force is developing a generic LoA review process with the aim of taking current good LoA review practices into account together with experiences encountered in the SESAR ODP Project. This review process will be shared with the appropriate European Working Arrangements for review and approval, upon completion (expected mid-2020).

## SESAR ODP EXPERIENCES

The SESAR ODP Project performed a large-scale review of high-altitude strategic restrictions in LoAs along multiple routes in the core area of Europe, with the participation of Maastricht UAC, DFS, SKYGUIDE, DSNA, AUSTROCONTROL and the participation of multiple Airspace Users. They reviewed the restrictions for each route against the performance of the traffic mix that typically flies each route, in order to assess how penalising they were. Where higher penalties were identified, the potential revision of the restrictions was studied, and when possible applied. The changes that were implemented within the ODP Project were typically in the sense of raising an altitude constraint, and were not large, e.g. they would raise the transfer flight level in the LoA by 2,000ft. Even though the fuel gain for each individual flight may not have been very significant, when the data were aggregated together, the overall gain for the environment turned out to be very large, due to how busy the routes were. The ODP report contains valuable information of the process that was followed, the challenges that were encountered by the team and recommendations based on their lessons learned.

For case studies on the development of a seasonal LoA in Switzerland, see Appendix Q1.

For a more detailed case study on the outcomes of the ODP study, see Appendix Q3.



# APPENDIX H: CCO / CDO FACILITATION

## KEY MESSAGE

The European CCO / CDO Task Force believes that CCO and, in particular CDO, can be facilitated through the provision of DTG, appropriate airspace design and the use of ATCO support tools.

The Task Force also promotes the provision of maximum flexibility to Flight Crews to manage their flight path, which will give them the opportunity to reduce their fuel burn. Arrivals should not be routinely forced to descend early in order to be below departures, as is often the case in current operations.

For optimised CCO / CDO from the fuel burn perspective, the European CCO / CDO Task Force would like to pass the following messages that support CCO / CDO facilitation, based upon detailed analyses that their members have undertaken:

- Arrivals should be kept above departures wherever possible;
- For certain aircraft types, a level-off in the climb may result in a lower fuel penalty than the same distance level-off in the descent – in such cases, from the fuel burn perspective, CDO could be prioritised over CCO;
- For departures, a track extension should mostly be avoided as all track extensions add on cruise FL kg per nm;
- If there is a choice between a track extension to facilitate CCO or a level-off without a track extension for a departure, a level-off may save more fuel than the CCO; and,
- At the strategic level (airspace design) and in tactical situations, more fuel may be saved by levelling off departures as opposed to arrivals.

Priorities for facilitating CCO and CDO include:

- Predictability;
- Closed flight path (distance to go);
- Timely descent clearance;
- Good ATC-Flight Crew coordination;
- Aircraft energy management (FMS or Flight Crew); and,
- Wind & temperature prediction.

In order to improve predictability and optimise the descent profile, published descent procedures should be very close to what is actually flown and should be followed by both ATCOs and Flight Crews. They should also not be cancelled on a regular basis.

While this can be easily achieved outside peak hours, for optimum traffic handling in busy periods at high-capacity airports, ATCOs may need to use tactical intervention, e.g. vectoring and / or speed control. These tactical interventions reduce the desired predictability that Flight Crews need to maintain the optimum descent profile. Early sequencing of aircraft can assist in increasing both the frequency and duration of CDO performed, especially in periods of high traffic density, by reducing the number of tactical interventions.

Implementation of advanced ATM tools for separation (like the examples shown below), sequencing and metering should further improve CDO facilitation. The frequent and continuous use of Controller tools - such as arrival management tools - is highly recommended.

Closed STARs offer sufficient predictability to fly an optimum descent profile; where Open STARs are implemented, or vectoring is used to tactically control traffic flows, they should be facilitated by the reliable provision of DTG to ensure predictability.

Any lateral, vertical or speed change after the descent has been initiated will result in the aircraft deviating from its computed optimal descent path. Shortcuts, speed reductions, higher tailwinds or intermediate altitude restrictions will leave the aircraft in a high-energy situation. On the contrary, extending the distance to be flown, requiring high rates of descent, higher headwinds or higher speed requirements, will create the need to use extra thrust at non-optimal altitudes and may result in inefficient intermediate level segments or even more inefficient low-rate descents.

ATC system support should provide the necessary functionalities in coordination and transfer systems to relay the necessary information related to optimising the descent profile to the Controller in charge before the Top of Descent.

## H1: Facilitate the provision of track miles / DTG

Where Open STARs are implemented, vectoring or speed instructions should give the Flight Crew predictability, wherever possible, via the facilitation of DTG to the crews. This can be achieved by the use of support tools such as PMS, AMAN, XMAN (provided any speed constraints are known before the ToD), T-bar or RNAV waypoints used as reference waypoints tactically on final approach.

Should tactical changes be required by ATC, the provision of regular and accurate DTG information from ATC to the Flight Crew is essential in allowing the Flight Crew to optimise the descent profile.

### CDO enhancement tool: T-bar and MergeStrip (HungaroControl)

Before the introduction of STARs in 2005, the main method for the management of arrivals at LHBP (Budapest Airport) was vectoring. Vectoring proved to be very effective when it came to delivering final spacing and separation but quite ineffective with regard for optimising flight efficiency. ATCOs tried to give track mile information on request to Flight Crews but the value of the expected miles to fly was only a rough estimation.

In 2005, HungaroControl introduced RNAV STARs to all runways. This proved to be effective in managing higher levels of traffic, but direct routings to interim points of the procedure sometimes caused problems for the Flight Crews since they did not know what to expect after the specific waypoint. Should they continue on the arrival procedure or make a base turn to the final? The difference could be 20-25 miles, which can produce enormous miscalculations when conducting a CDO.

Analysis was made and showed that vectoring without track mile information is the biggest showstopper for the optimisation of CDO. The solution was to design and introduce so-called T-bar procedures to all runways (see figure 32).

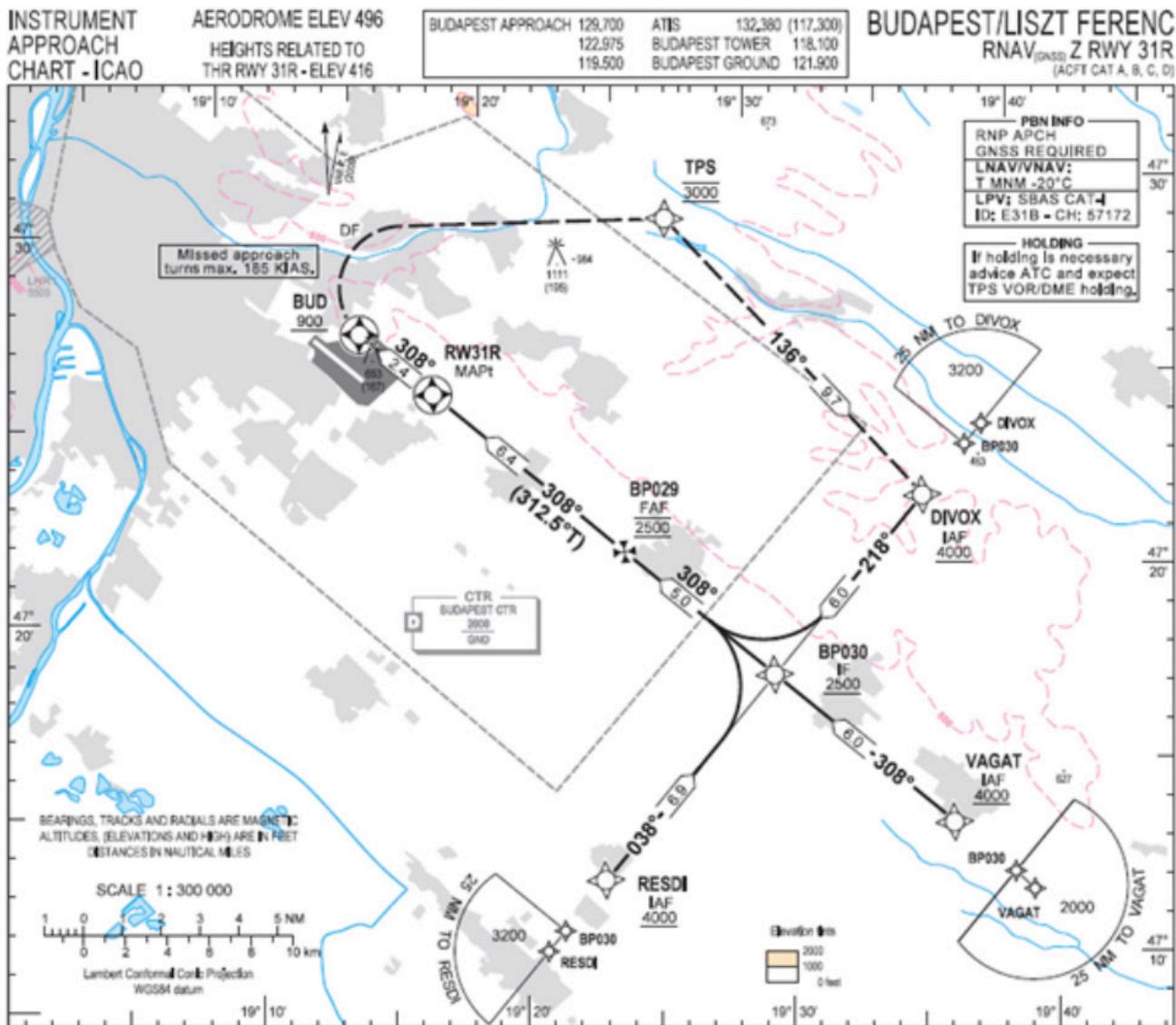


Figure 32: T-bars at LHBP

In high level traffic density situations ATCOs still use the long STARs and tromboning but in low and medium traffic most (if not all) aircraft are coordinated and sent from approximately 150-200nm from the airport to the appropriate IAF points (RESDI, DIVOX and VAGAT for example). The Flight Crew immediately (before reaching the ToD) know the exact routing that must be flown to touchdown, so effective CDO is made possible.

However, for sequencing reasons, highly sophisticated speed control is required for T-bar operations, which is very demanding for the ATCOs so HungaroControl developed a concept and a software, the so-called CDO-enhancement tool called MergeStrip. MergeStrip is not an AMAN but a tool dedicated to help with speed control and sequencing of the arrival aircraft.

The software is a dynamic spacing tool, which always calculates the shortest possible route to the IAF of the T-bar procedure from any direction and helps the ATCO to apply the necessary speed control and issue shortcuts as soon as possible and brings a new way of representation of the current traffic situation both horizontally and vertically.

## THE MERGESTRIp – A HUNGAROCONTROL SOLUTION

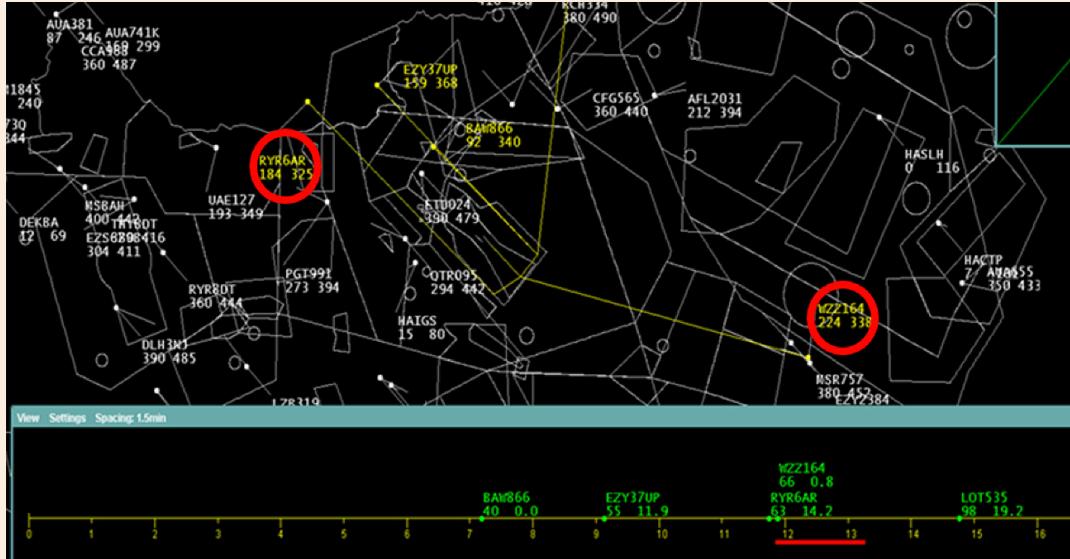


Figure 33: screenshot of T-bar and MergeStrip at LHBP with two aircraft in conflict

In Figure 33 it can clearly be seen that RYR6AR and WZZ164 are both flying to the T-bar points but they are conflicting (in spite of arriving from different sectors) so speed control is advised:

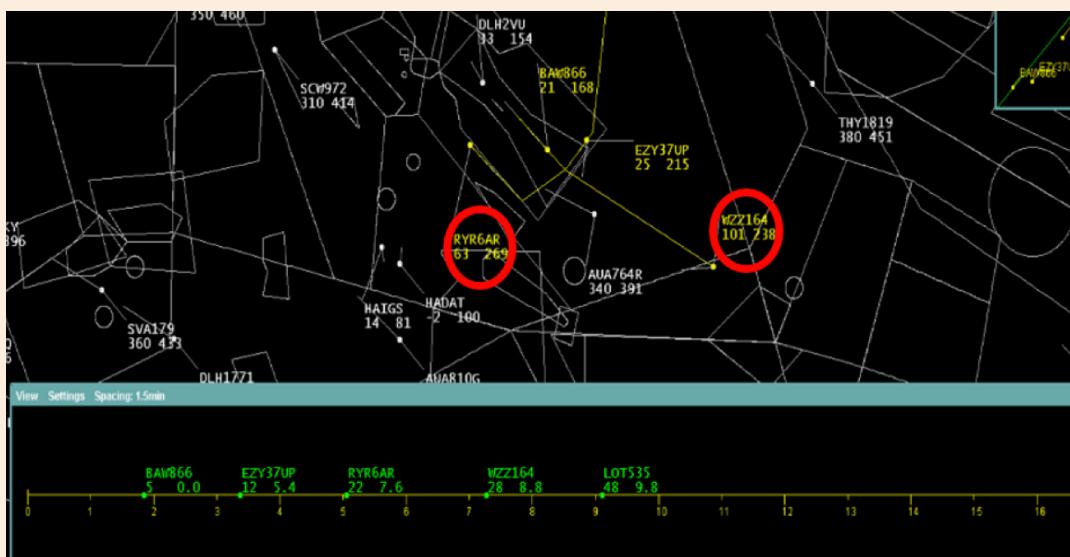


Figure 34: screenshot of T-bar and MergeStrip at LHBP with conflict resolved by speed control enabling CDO

After the speed control the software shows that the conflict is dissolved and all aircraft are able to fly via the shortest possible route conducting a CDO – see Figure 34.

The software does not give any speed control advisory but represents the current traffic situation in a new form, the speed control and / or vectoring is still the responsibility of the ATCO. Therefore, a certain level of experience is required but the ATCOs can monitor the real time effects of their actions and can make further adjustments if needed. Meanwhile the Flight Crew are always aware of the exact (closed) path to be flown and (even under speed control) can achieve a CDO.

## DTG – THE BULATSA SOLUTION

In another example, RNAV procedures were introduced at LBSF (Sofia Airport, Bulgaria) in 2016. Previously, the main method for managing the arriving traffic was radar vectoring. When ATCOs tried to provide DTG information to the threshold, the ATCOs found that in some situations it was difficult to calculate precisely the value. In order to facilitate the provision of DTG, BULATSA introduced automatic calculation of DTG in its radar system. The functionality was based on the aircraft trajectory extracted from the flight plan and updated according to the intention of the ATCO. Whenever the trajectory of the aircraft needs to be changed, the ATCO draws a new trajectory on the screen. The DTG appears as a small number close to the symbol of the aircraft and is updated after any trajectory update.



Figure 35: Screen shot of Bulatsa radar system at Sofia airport showing automatic calculation of DTG

## H2: Speed and energy management

One of the main parameters that affect the descent profile and corresponding fuel burn is the speed at which the descent is carried out. Fuel consumption per mile is lower at higher altitudes, which is why aircraft want to cruise at higher levels. In an ideal world, aircraft should stay at the cruising level until the ToD point where they can begin their descent in idle thrust. From the moment the idle thrust descent starts, the aircraft trades potential energy for kinetic energy, descending in what is basically a 'free ride' from the fuel burn point of view.

Leaving the cruise FL before ToD means that the descent will have to include one or more segments where the engine is not on idle thrust. These can be level segments or segments where the descent is continuous but at a lower rate than at idle thrust. Regardless of where the descent starts, during the descent the fuel consumption per minute is lower than at cruise, because the aircraft is 'going downhill'.

The fuel burn is minimised only when the CI is set to zero (maximum range speed); the higher the CI, the later the descent starts and the faster the descent speed will need to be (because the aircraft goes 'downhill' more steeply). When the descent starts too early, the overall fuel consumption is always larger if the descent speed that was originally calculated is maintained.

Leaving the cruise FL after ToD means that the cruise phase, in which the engine is not on idle thrust, has been unnecessarily long. The descent speed will need to be faster than planned, and the descent angle will need to be steeper. In some cases, the aircraft will have to apply drag (airbrakes, early flap extension or even early landing gear extension) to lose the excess energy, which will have an even higher penalty in terms of fuel burn. In extreme cases, the flight path will need to be extended in order to give the aircraft sufficient miles to descend.

Descents are normally performed in three phases on a constant Indicated Air Speed (IAS) / Mach descent speed schedule:

- Constant Mach number is maintained until the crossover altitude;
- Constant indicated air speed is maintained until approaching 10,000ft; and then,
- 250kts IAS is maintained below FL100, until the aircraft decelerates for landing.

The distance travelled in nautical miles and the indicated speed at which the descent is performed above 10,000ft depend on several factors, but the two main ones are selected cost index and the weight of the aircraft. The same aircraft may fly the same approach with different speeds, depending on these two factors.

The FMS or the Flight Crew calculates what the optimal descent speed based on CI and weight would be. Therefore, the descent speed and associated trajectory depend on airline policy and its cost index, aircraft type, meteorological conditions, weight, etc.

The difference between low and high CI scenarios (i.e. between CI1 and CI150 in an Airbus aircraft) may result in speeds between approximately 250-340kts. The difference in fuel consumption between the two scenarios could result in fuel burn differences of up to approximately 75-80kg, together with three minutes' longer flying time for a single aisle aircraft.

In today's environment, most aircraft fly at a low CI, which means that in busy airspace the three minutes time savings from the higher CI in the descent phase are often not actually made. This is because, any aircraft flying with a higher-CI may be asked to reduce speed in order to make it fit into the flow of slower flying aircraft.

In current operations, the intended descent speed is not communicated by the airspace user to the ground in the ATC flight plan. Therefore, the amount of energy that needs to be dissipated is not known by the ATCO.

Furthermore, in high traffic periods, tactical intervention from ATC might be needed to accommodate the flow of arriving aircraft with different descent and approach speeds. When speed constraints are known to the Flight Crew before starting the descent, the ToD can be adjusted accordingly, so that the CI is superseded by this new descent speed and the fuel burn can be minimised within that constraint.

After the descent has started, an ATC instruction to reduce speed will cause the aircraft to be above profile, and an instruction to increase speed will cause the aircraft to be below profile. In a similar way, ATC instructions to reduce / increase the vertical speed will leave the aircraft above / below the optimum path.

In closed-path STARs, any tactical small speed adjustments should only be considered, preferably over vectoring off the procedure, as predictable DTG is still accurate and the excess/lack of energy that the speed adjustment creates is manageable by the crew. Speed control is most effective when a small correction is made early on in a procedure and given time to take effect, or, when speeds are a part of the procedure.

As explained in Appendix F, the Tailored Arrival concept with speed control should be used to adjust the timing and descent profile of the aircraft, allowing for the completion of the clearance, as this enables the aircraft's automation to make its own calculations. This provides:

- The highest level of predictability for ATC;
- Fuel savings for the airlines; and,
- Noise and emissions reductions for surrounding communities.

One area of good practice to be used in optimising CDO performance would be a harmonised descent speed in the AIP. In practice, a harmonised descent speed calculated to fit the preferred descent speed of the traffic mix without forcing a fraction of the flights to fly below C10 (typically approximately 250kts after cross-over) could be a better option because it would allow the Flight Crew to factor it into their descent planning. With prior planning, speed control can be factored in by the Flight Crew and accomplished without the use of drag or level flight.

Specific speed restrictions, often used to maintain separation between succeeding aircraft, may be required to allow CDO from cruising levels in high traffic density areas. In setting any permanent speed restrictions, the distance to the runway along the theoretical flight path should be taken into account.

Speed constraints reduce the flexibility of the CDO but can aid optimum traffic sequencing, and so less tactical ATCO intervention. Aircraft / FMS-specific limitations should also be taken into account. Proposed permanent speed restrictions need to be coordinated between all stakeholders prior to finalising them.

In general, speeds from higher levels should not be less than 280–290kts IAS. An example chart notation could be "... maintain 280kts IAS until leaving 10,000ft AMSL". Flight Crews would be expected to programme their FMS to pick up the speed schedule of 280kts as the aircraft descends from the Mach regime.

Even though the planned speed control might not coincide with the most economical descent speed of all aircraft, it may be seen as the best compromise between capacity constraints and CDO facilitation.

ATCOs should not change speed constraints given to aircraft unless they are required tactically. In low traffic situations, cancelling speed constraints in a timely manner may allow the Flight Crew to fly the most optimum descent speed. It should be noted however that after the cancellation of speed constraints, this may require the Flight Crew not only to change the selected speed but also to program a new speed into the FMS, as only with the programmed speed will the FMS be able to calculate the optimal flight path.

Another consideration should be that, when implementing new airspace designs or procedures, it might be prudent for ATCOs not to cancel non-optimum speed constraints, even if the traffic situation allows. This is because flying the full procedure, including any related speed constraints, will be beneficial as a training drill for both Flight Crews and ATCOs while ensuring situational awareness of the new procedures. Once the new design / procedures are fully implemented, the non-optimum speed constraints may be relaxed in low traffic periods where the situation allows.

Any further ATCO tactical intervention could use the rules of thumb such as, for a descending aircraft, a speed reduction of 10kts will give a fuel saving of 10kg (1kg/kt) and a longer flight time of 30 seconds. Therefore, to go from an average speed of 280kts to 270kts during descent saves 10kg fuel (32 kg CO<sub>2</sub>) and adds 30 seconds of flight time. Likewise, accelerating a climbing aircraft will reduce the rate of climb, which could otherwise have been used for vertical separation purposes. Later resumption of normal speed will minimise the impact on fuel burn.

From a system support point of view, the downlink of the managed descent speed to ATCOs could lead to a better predicted speed that could be incorporated in any sequencing tool – like AMAN – and would help the ATCO to identify the optimum ToD of each aircraft.

When possible, the maximum of flexibility should be given to the Flight Crew to manage their aircraft in order to give them the opportunity to optimise the fuel consumption. Furthermore, should "descend when ready..." instructions be given by ATC, they should not be followed up by "increase rate by XXft/min" i.e. the Flight Crew should be left to optimise their profile where possible.

The discussions in this appendix highlight some of the challenges from the ATC side in understanding the energy situation in the cockpit and the impact that ATC clearances may have upon Flight Crew workload and the implications for the Flight Crew in maintaining the optimal climb and descent profiles. These factors provided the impetus for the European CCO / CDO Task Force to develop training material for ATCOs relating to aircraft energy management – see Appendix I.

## H3: Horizontal versus Vertical CCO / CDO facilitation

When ATCOs are faced with the decision of how to separate climbing / descending traffic, via level-offs or track extensions, there are different solutions depending on the individual circumstances and local conditions.

One method of tactical intervention may be instructions to provide vertical separation or horizontal separation by using either shortcuts ("direct to" instructions) or track extensions. While shortcuts without any level-offs may be considered the most efficient intervention, if a shortcut to a climbing aircraft or a track extension to a descending aircraft does not solve the conflict as the ATCO does not anticipate the conflict in advance, then it is likely that both aircraft in the conflict situation may have to be levelled off. That would be the worst-case scenario, as both horizontal and vertical penalties apply. This could be worsened by the fact that most pilots on the descent would then cut speed during the level-off to dissipate energy, increasing it back when re-cleared to descend. That reduction in speed would make the conflict last for a longer duration. On the contrary, the climbing crew might, if conditions allow, maintain thrust and increase speed during the level-off, minimising the time of crossing and the fuel penalty, as the energy can be converted into higher rate of climb once re-cleared. For the descent phase, extra track miles might not mean a level segment, as the crew can adjust the vertical speed. Therefore, unless the track extension is too long, it is difficult to assess what the extension means in terms of fuel. Idle descents are normally (as a rule of thumb) flown with a vertical speed of between 1,500-2,000ft/min, so if a track extension is required for a descending aircraft, the crew might select a lower rate of descent of at least 500ft/min during the descent.

If separation needs to be provided between an arrival and a departure, it may be more efficient to provide horizontal separation between them by extending the path of one of them.

Deviating an aircraft to achieve lateral separation of 5nm (en-route) or 3nm (TMAs) rarely adds more than 20 seconds to the flight time, and this is often more efficient than providing vertical separation through level-offs. Longer path extensions, however, of more than 30-45 seconds for instance, would likely generate more fuel burn than the fuel savings derived from CCO or CDO.

When achieving horizontal separation is either not possible or would require path extensions longer than 30-45 seconds, it could actually be more efficient to clear both aircraft to level off briefly (the arrival above the departure) until they are clear of each other. The level-off clearances should be calculated in order to minimise the length of the level segments.

The work of the European CCO / CDO Task Force, particularly in analysing fuel burn data in different operational situations, has revealed several interesting sets of information. The Task Force would like to introduce some of these ideas into the Action Plan. The Task Force does not wish to make any recommendations on how the outcomes of the analyses should influence ATC CONOPS or aircraft operator instructions in the OM. However, the Task Force would like to illustrate these findings to stimulate future discussions.

It is important to note that these findings have been calculated using actual operator data as opposed to assumptions on fuel flow rates.

### **Prioritisation of a descending aircraft over a climbing aircraft:**

When an ATCO is faced with a decision concerning a potential conflict between a climbing and a descending aircraft where a level-off should occur, multiple factors (aircraft types, traffic flow situation etc.) come into play, as a 'one size fits all' solution is not available.

When asked whether ATC should prioritise either the flight profile of a climbing aircraft or a descending aircraft as a tactical option in a one for one comparison, Flight Crew will almost unilaterally respond that the climbing aircraft should always be prioritised as it is heavier and therefore has a higher fuel burn and therefore, CO2 emissions. Current practices reinforce this thinking.

Analysis by Task Force members however has revealed that it is actually the fuel burn differential between optimum and sub-optimum flight levels for heavier and lighter aircraft, that is the most important factor to take into consideration. Take for example an A340 as can be seen in Figure 36.

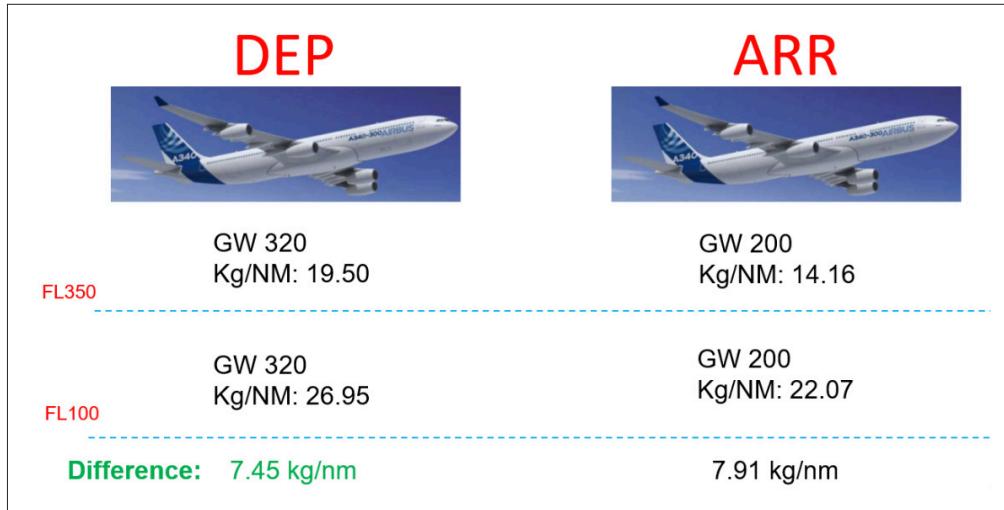


Figure 36: Highlighting inverse Specific Range differential at cruise / low level FLs for a heavier (departure) and lighter (arrival) A340

In this example, it can be seen that **the inverse Specific Range<sup>24</sup> differential** between the cruising level (FL350) and an intermediate lower level (in this case, FL100) **for a heavier aircraft** (in climb) **is smaller than for the same aircraft when it is lighter** (in descent).

Therefore, initial analysis shows that prioritising a descending aircraft over a climbing aircraft **may** actually save overall fuel as the higher penalty (in inverse Specific Range differential) for a level segment is avoided.

A difference of 0.46kg/nm may not sound like a lot but if the arrival was levelled-off for five minutes to allow the departure to climb, this would actually result in additional fuel burn of approximately 15kg fuel (assuming 6nm / minute). The same can be seen for an A320, see Figure 37.



Figure 37: Highlighting inverse Specific Range differential at cruise / low level FLs for a heavier (departure) and lighter (arrival) A320

24- Specific Range is the amount of distance flown by a unit of fuel burn. The inverse of this value (kg/nm) is used to check how much fuel is burned per extra nautical mile or level segment distance. Specific Range is used so that the variable of speed does not complicate the scenario.

In this example the inverse Specific Range differential may be only 0.33kg/nm but again, if the arrival was levelled off for five minutes to allow the departure to climb, this would actually result in additional fuel burn of approximately 10kg fuel (assuming 6nm / minute).

*Note: In these examples, the Specific Range is used to highlight different fuel burn differentials as the fuel flow figures are sourced from different performance tables: the long range cruise fuel tables for FLs up to FL240, and M0.78 / M0.82 fuel burn tables (nominal A320 and A340 cruising speeds respectively) for FLs above FL290. When comparing fuel burn above FL290, fuel flow figures (in kg/hr/engine) may be used. It should be noted that in general, fuel flow figures show higher fuel burn levels than with the Specific Range.*

It should be reiterated that the objective of this analysis is not to make recommendations for ATC CONOPS or a proposal for updating aircraft operator instructions in the OM. The objective is to encourage debate, further analysis and understanding of the factors that may influence the optimisation of fuel burn in climb and descent.

Initial analysis shows that taking into account certain factors such as aircraft type, speed, weight, cost index and level segment altitude, for some aircraft types, prioritising a CDO over a CCO may provide more fuel savings than prioritising a CCO over a CDO.

**What is certain is that it is not the aircraft weight (and therefore, fuel flow rate) that should be the primary factor in determining which aircraft should be prioritised in a CCO versus CDO situation.**

It is recommended that a more complete analysis be undertaken to see whether such a trend may be found for more aircraft types.

When the level-offs are needed below FL100 for departures, and FL70 for arrivals, then there is an added complexity with noise impacts. In this case, a level-off on a descending aircraft that leaves the arrival above profile will have a greater negative effect on noise, because it may lead to the deployment of airbrakes or early flap or landing gear extension. On the other hand, forcing the arrival to descend earlier so it will be below the departure means the arrival will be lower for a longer time, thereby also increasing the noise.

#### **Prioritisation of an optimised climb profile / track extension over a level-off:**

If a question were to be asked to both ATCOs and Flight Crew whether they would prefer a track extension for a departure to facilitate a perfect CCO compared to a level-off (and therefore no CCO), with no track extension, the vast majority would likely answer in the affirmative. Flight Crews desire to fly the optimal climb profile whilst ATCOs are taught to enable CCO whenever it is possible.

However, when looking only at fuel burn considerations, one point should always be understood:

*"If you add a track extension, the additional track distance will be always be flown at the cruising level fuel flow rate".*

This is because regardless of the track extension, the time spent 'climbing' will be approximately the same in both scenarios regardless of how long the track extension is or the duration of any intermediate level segments. Therefore, any track extension will result in additional fuel burn at the cruising level fuel flow rate.

Calculations may help to demonstrate this point. Looking at one example, Table 12 shows fuel penalties (in kg/nm) for level segments at different flight levels for a medium-sized jet aircraft, commonly flown in Europe, at nominal weights.

GW=77.000 Kg / ISA + 0 °C / Wind= 0 KTS					
Level Off Altitude	Level Off IAS (KTS)	Level off TAS (KTS)	FF (KG/Hr)	Fuel consumption (KG/Nm)	Level Off penalty (Kg/Nm)
5000	250	268	2566	9.57	3.64
12000	280	332	2734	8.23	2.30
19000	280	369	2654	7.19	1.26
26000	280	411	2642	6.42	0.49
33000	273 (CI 10)	448	2658	5.93	0

Table 12: Fuel flow rates for cruise at different flight levels for a medium-sized jet aircraft, commonly flown in Europe

The figure 5.93 in Table 12 refers to the fuel burn penalty in kg/nm for a 1nm level-off at FL330, i.e. the fuel flow rate when cruising at FL330. Therefore, if a departing aircraft has a track extension of 1nm in the climb (to facilitate CCO); this will result in an additional fuel flow of 5.93kg.

The other boxes in orange indicate the additional fuel flow of a level segment at lower levels compared to the fuel flow at FL330 e.g. at FL190 the fuel flow is 8.23kg/nm, a difference from 5.93kg of 2.3kg.

Therefore, if an aircraft is levels off for 1nm at 5000ft instead of flying a CCO, the additional fuel burn for that 1nm level-off will be the difference in fuel flow between 9.57kg/nm and 5.93kg/nm i.e. only 3.64kg. Therefore, a 1nm level-off in the climb with no CCO and no track extension, may actually result in less fuel burn than a perfect CCO and a 1nm track extension. This is the same regardless of aircraft type. This can be visualised in the following examples.

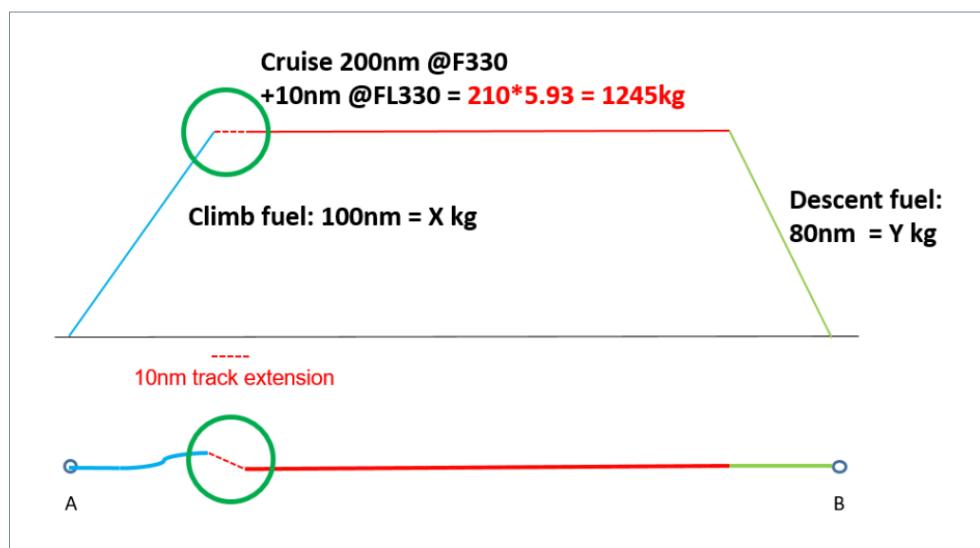


Figure 38: Demonstration of the fuel burn implications of a 10nm track extension to facilitate a CCO for a specific medium-sized jet aircraft, commonly flown in Europe

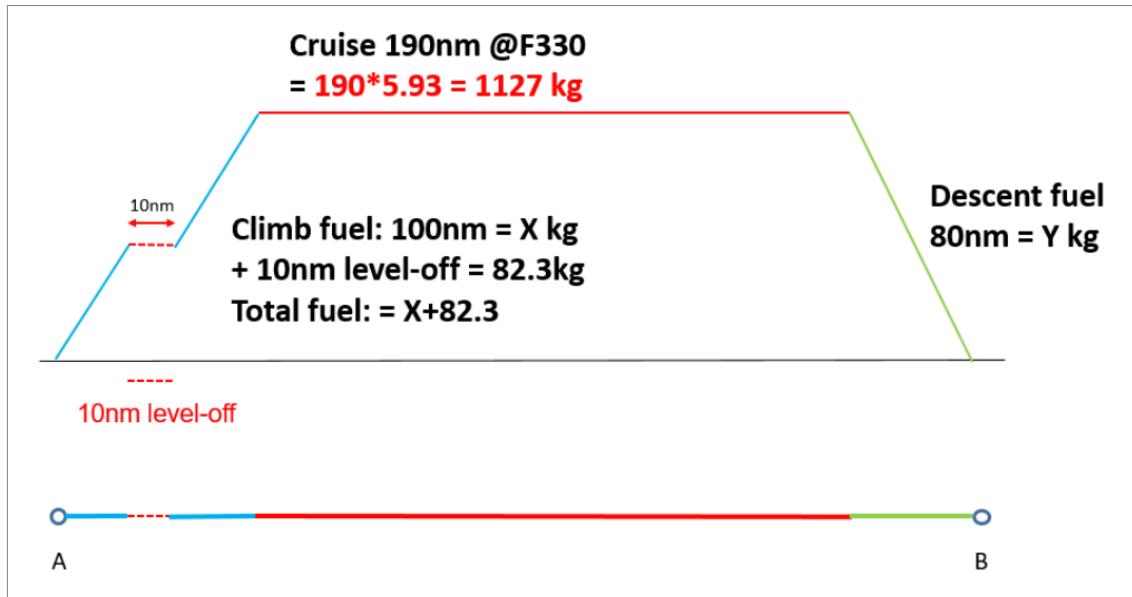


Figure 39: Demonstration of the fuel burn implications of a 10nm level-off at FL120 and no track extension for a specific medium-sized jet aircraft, commonly flown in Europe

In the examples shown in Figure 38 and Figure 39, the length of the optimal climb phase is 100nm with 80nm for an optimal descent phase. The direct distance to be flown in the cruise phase would therefore be 200nm.

Taking into account the data in Table 12, Figure 38 shows that the 10nm track extension facilitates a perfect CCO but results in 10nm of fuel burn to be added to the cruise phase, or 59.3kg fuel. This results in a total fuel burn for that flight of  $200*5.93 + 10*5.93 + X + Y$ , a total of 1245.3kg fuel (+X and Y).

In Figure 39 however, although the climb phase is extended by 10nm, the fuel burn for the actual climb remains as X with an additional 10nm of level flight flown at the higher rate of 8.23kg/nm because of the level-off at FL120. Because 10nm of the cruise phase is flown at a sub-optimal level (FL120), the cruise distance at the cruising level is therefore reduced to 190nm. This results in a total fuel burn for the flight of  $190*5.93 + X + 10*8.23 + Y$ , a total of 1209kg fuel (+ X and Y). For heavier aircraft e.g. B744, the fuel savings in exactly the same scenario would be 156kg fuel.

Therefore, if there is a choice between a track extension to facilitate CCO or a level-off without a track extension, even for a heavy aircraft a level-off may save more fuel than the CCO.

In the examples demonstrated above (based on the figures detailed in Table 12), the fuel burn for a 1nm track extension (5.93kg) to enable a perfect CCO is ~equivalent to a 12nm level-off at FL260 ( $0.49*12 = 5.88$ kg fuel) whilst a 1nm track extension (5.93kg) is ~equivalent to a 1.5nm level-off at 5000ft ( $3.64*1.5 = 5.46$ kg fuel).

The situation may however be further complicated. Tactical interventions are not however, simple fuel calculations, as ATCO track extensions are more likely to be subtle 5 or 10° turns.

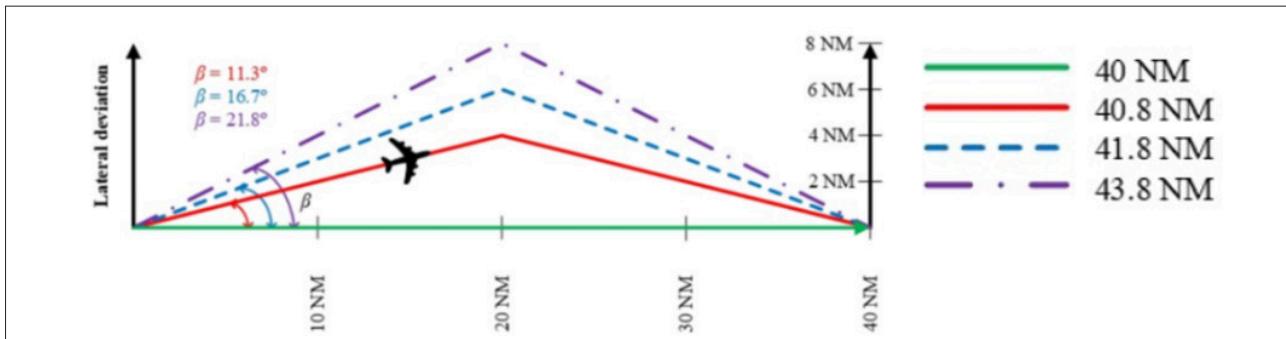


Figure 40: track mile extensions for approximate 10, 15 and 20° tactical vectors

In such circumstances, Figure 40 shows that a 15° tactical vector for 20nm would result in a track extension of 1.8nm. For the aircraft types (medium / B744) in the previous examples this would be an additional 11 / 42kg fuel to enable a CCO respectively. For both these examples, this would result in more fuel burn than a 2nm level-off at 5000ft or a 5nm level-off at FL120.

*It should be noted that these calculations are derived using complex data and tools that are not currently available to ATCOs for complicated calculations, especially in high-workload tactical situations.*

CCO and CDO facilitation through horizontal and vertical optimisation is a complex subject with many interdependencies. For example, in a TMA environment, climb, and track extension may be preferred over level-off, to expedite traffic outside of the TMA environment in to freer airspace where better tactical handling of the flights can be made. In this case, the increased fuel burn may be offset by enabling the possibility to climb, resulting in a reduction in noise exposure on the ground due to the continuous climb.

Taking all this into account, there are a number of high-level principles that should be understood:

Bearing in mind ATC CONOPS, airspace and procedure design principles and understanding of ATCO / Flight Crew behaviour, from a purely fuel burn and emissions reduction perspective, especially for departures, a track extension should be avoided where possible as all track extensions add on cruise FL kg of fuel burn per nm.

If there is a choice between a track extension to facilitate CCO or a level-off without a track extension for a departure, a level-off, and therefore non-CCO, may actually save more fuel than the CCO, of course depending upon aircraft type, weights and local conditions.

#### **Arrivals above departures:**

It is common across Europe to see procedures that routinely force arrivals to descend early so that they are well below departures. This is a useful technique to achieve strategic separation of traffic flows that may be necessary in busy airspace, but it may result in arrivals flying a non-optimal descent profile. The Task Force agrees that currently, there is insufficient awareness that early descent causes extra fuel burn and that it would be better to give Flight Crew, conditional descent instructions.

The SESAR ODP demonstration looked into the interdependencies between arrivals and departures and concluded that a very simple rule should be applied: arrivals should be kept as high as possible.

## THE 'ARRIVALS ABOVE DEPARTURES' PRINCIPLE

If an arrival flight and a departure flight are crossing, it is not efficient to force the arrival to descend early in order to be below the departure when they cross. Instead, it is more efficient in terms of fuel to level-off the arrival flight in order for it to stay high above the departure. Consequently, arrivals should not be routinely forced to descend early in order to be below departures, as is often the case in current operations. The reason for this is twofold. On the one hand, an early descent makes aircraft burn extra fuel, and therefore staying high saves fuel. On the other hand, the differential between the fuel flow at optimal and sub-optimal levels is higher for lighter aircraft (i.e. arrivals) than for a heavier aircraft of the same type, therefore the fuel burn penalty for a level-off in descent is higher than the same penalty in the climb. In addition, the intermediate level that the departure and the arrival flights should be cleared to should be calculated so that the time of level-off is as short as possible.



Figure 41: Arrivals above departures principle

Keeping arrivals high is in general more challenging from both an ATC perspective and a flight crew perspective: when aircraft are lower, ATC has more flexibility to handle the aircraft in terms of speed reduction or path shortening, because they have already lost a large part of their energy. In contrast, an arrival aircraft that is high needs to lose energy in sufficient time to fly at a stabilised speed and may not be able to reduce speed or accept a direct routing as readily as it would do if it were lower. **This principle should therefore be applied with common sense: arrival aircraft should not be routinely forced to descend early in order to avoid a level-off above a departure at all costs, but they should not be forced to stay higher than their FMS optimum profile either.**

#### **Conclusions:**

This section highlights a number of scenarios that the Task Force and SESAR have analysed with actual fuel burn data. Whilst the decision to optimise CCO versus CDO or HFE versus VFE should be determined at the local level, the Task Force concludes that consideration of the following messages should be passed in the Action Plan:

- Arrivals should be kept above departures wherever possible;
- For certain aircraft types, a level-off in the climb **may** result in a lower fuel penalty than the same distance level-off in the descent – in such cases, from a fuel burn perspective, CDO could be prioritised over CCO;
- For departures, a track extension should mostly be avoided as all track extensions add on cruise FL kg per nm;
- If there is a choice between a track extension to facilitate CCO or a level-off (non-CCO) without a track extension for a departure, a level-off may save more fuel than the CCO; and,
- At the strategic level (airspace design) and in tactical situations, more fuel may be saved by levelling off departures as opposed to arrivals.

As detailed at the beginning of this section, the aim of disseminating these messages is not to recommend specific stakeholder actions. However, this information is shared with the objective to stimulate new discussions on how the understanding of fuel flows under different circumstances may actually lead to new ways of operating that could reduce fuel burn.



# APPENDIX I: TRAINING FOR ATCOS

## KEY MESSAGE

The European CCO / CDO Task Force has proposed specific updates to the Common Core Content training objectives for Area and Approach ATCOs. The objective of these proposals is to ensure that more content is added on facilitating CCO / CDO, that more information is available on aircraft energy management and that simulation exercises on CDO are taught earlier, and in more detail, in the ATCO training timeframe.

The Task Force has also developed an ATCO refresher course on Aircraft Energy Management that is available on the EUROCONTROL Training Zone.

The European CCO / CDO Task Force has proposed specific updates to the training objectives for Area and Approach ATCOs. This should ensure that more content is added to the training objectives relating to CCO / CDO, that more information is available on aircraft energy management and that simulation exercises relating to CDO are taught earlier, and in more detail, in the ATCO training timeframe.

These proposals have been made for the ATCO Common Core Content (CCC) training material:

- Mandatory content on CCO (previously optional);
- Creation of specific CCO / CDO Objective with higher taxonomy level to indicate more simulation exercises required than is currently the case and
- A new proposed objective on ATCO training: 'appreciate ATCO actions that may contribute to the Flight Crews ability to fly an optimal CDO profile' also known as aircraft energy management.

In addition, a CDO refresher training for ATCOs will be available in 2020 as an eLearning course on the EUROCONTROL Training Zone. ANSPs and Training Organisations may use this course as part of their ATC refresher training programme. Individuals will also be able to access and register for the course.

The course may be accessed through the following link: <https://trainingzone.eurocontrol.int>

**The ATCO refresher training on Aircraft Energy Management includes the following subjects and topics:**

0.1	Welcome to the course	
<b>Subject 1: Introduction to CCO/CDO</b>		
1.1	What is CCO / CDO?	
1.2	Benefits of CDO	
1.3	We need to talk about predictability	
<b>Subject 2: Factors affecting CCO/CDO</b>		
2.1	Impact of unstabilised approach on safety	
2.2	Capacity	
2.3	Impact of airspace and procedures	

<b>Subject 3: Procedure design</b>		
3.1	Designing arrival routes	
3.2	Closed path designs	
<b>Subject 4: Aircraft energy management</b>		
4.1	Basic laws of physics and aircraft management	
4.2	Impact on descent profile	Includes: • Type of aircraft • Weight • Speed • Cruising Level and Cost Index
4.3	Speed management	Includes: • ECON speed • Selected speed
4.5	Rule of Thumb	Includes: • ToD in NM-Alt/3 + margin • 1kt reduction = 1kg saved but 3s more • Early/late descent
<b>Subject 5: FMS and AutoPilot basic functionalities</b>		
5.1	Vertical profile calculation	Includes: • Wind input • Speed selection • STAR inputs & restrictions
5.2	AP descent modes	Includes: • Managed modes from the FMS • Vertical speed
<b>Subject 6: Clearances and phraseology</b>		
6.1	Arriving aircraft	
6.2	Departing aircraft	
<b>Subject 7: How ATC can facilitate CDO</b>		
7.1	Some general guidelines	
7.2	Speed control	
7.3	Vectors and DtG	
7.4	CCO vs CDO	
<b>Subject 8: References</b>		
8.1	References for further information	
<b>Subject 9: Course Evaluation</b>		

Table 13: ATCO refresher training subjects





# APPENDIX J: AIRLINE STANDARD OPERATING PRACTICES AND GOOD PRACTICE MATERIAL

## KEY MESSAGE

**The European CCO / CDO Task Force recommends that Aircraft Operators adopt guidelines when creating policies and SOPs on CDO, to improve awareness and enhanced CDO performance.**

**The Task Force has developed a proposal for a CDO Policy together with supporting guidelines based on existing Aircraft Operator good practices.**

From previous analyses undertaken by EUROCONTROL, together with the experiences of certain States such as the UK, Belgium, Germany and Sweden, it is clear that efficient performance of airlines and their contribution to the levels of CCO / CDO performance, is a reflection of the mentality and understanding of individual Flight Crew members.

The survey sent out by the European CCO / CDO Task Force yielded surprising results. Over 120 responses were received to questions asking if airlines carry out training on CDO, maintain CCO / CDO SOPs, produce CCO / CDO good practice guidance material for individual airports, and if they measure CCO and / or CDO performance.

A large percentage of airlines, however, do none of this. It appears that while most airlines are interested in flying CDO to all destinations, few are really CDO-focused, as only 33% of airlines surveyed had a Standard Operating Practice on CDO, and less than 25% of airlines measured CDO performance internally.

When checking some examples of these SOPs on CCO / CDO, it transpired that guidance material was more likely to include simple text suggesting that Pilots 'fly as much CDO as possible' or a similar statement, as opposed to detailed recommendations.

**The European CCO / CDO Task Force does not consider this sufficient, as more detailed guidance material should be developed.**

For operational aspects, it is vital that SOPs are compatible with / built around CDO techniques that promote CDO being undertaken where possible. However, simply just promoting CDO may be considered insufficient to drive performance improvements.

In certain cases, developing specific descent optimisation may not be possible due to different business models e.g. Business Aviation. Business Operators may not fly regularly to the same destinations multiple times per day and thus may not benefit from local knowledge like other Operators. In this case, it is important that Operators both develop SOPs and support Pilot Awareness through line training and annual assessments (see appendix K).

Where collaborative forums exist (see appendix N), stakeholders should be encouraged to use such a forum to make a general recommendation for the harmonisation on SOPs amongst airlines for a specific airport. In the same way, airlines should be encouraged to adopt SOPs and work with the ANSP to facilitate the creation of harmonised SOPs especially if the airport concerned is their home base.

To an extent, SOPs may also be developed for CCO albeit with a limited influence on CCO performance e.g. requesting further climb when approaching the cleared level, stating the RFL on first call etc. As Flight Crew influence on CCO performance is limited, this appendix proposes to concentrating on recommendations for a CDO policy and related guidelines.

The European CCO / CDO Task Force considers that developing a specific CDO policy, procedures and flying techniques for CDO for each aircraft type, is a good practice that should be recommended, as it harmonises Flight Crew behaviour and increases CDO awareness. A set of principles have been identified from existing airline good practices.

## RECOMMENDED CDO POLICY

As per company policy, the following are considered basic principles that all airlines should adhere to:

- CDO should be performed whenever practicable and operationally safe to do so;
- For fuel saving, it should be recommended to commence descent from cruising altitude at the optimum / FMS ToD whenever practicable and operationally safe to do so;
- Idle thrust during descent should be used as much as possible;
- Text included by the aircraft operator in the OM should provide "guidance material on descent management" including information to its Pilots on how to optimise CDO all along the descent phase starting from ToD until the final approach, covering for when traffic situations do not allow for a perfect CDO;
- Airlines often produce additional specific airport safety briefings whenever it is felt necessary to complement AIP information. It is also considered a good practice to include a section that deals with environmental issues in these briefings (normally published in OM (C). For example, the CDO procedures for each aircraft type could be tailored to different airports / approaches and be part of the airport briefings in the OM (Part C). The objective is to give Flight Crews the supporting documentation necessary to optimise CDO and Flight Crew performance at different airports where otherwise, the information might not be available. For example, the information provided could be a special briefing for a particular airport, runway and arrival route, giving hints supporting the Flight Crew with local details, which can be used to improve the awareness and understandings of the specific local conditions and how they may affect the ability of the Flight Crew to fly an optimised profile;
- Airlines are recommended to produce and disseminate to all, should appropriate effort be available, detailed information that describes the recommended Fuel and Cost Saving Guidelines for its Flight Crew, and regularly update the manual. This information can cover a combination of aircraft types that the airline deems to be of relevance. Its production will almost certainly require collaboration among several airline departments, working together to achieve an increase in the number of CDOs flown by the airline's Pilots, to deliver improved fuel efficiency and less emissions per flight. This information could include specific guidelines on descent planning, describing what to do in the case of early or late descent clearances;
- Monthly or other timely bulletins containing CDO performance information should be communicated to airline staff and Flight Crew;
- Promotion of crew feedback on CDO performance is a very useful mechanism for highlighting potential issues in individual or group CDO performance. If performance data is shared from outside the airline e.g. by an airport, the airline can work with the airport to ensure that measurements are accurate, with both parties working together on identifying, and mitigating, the causes of inefficiency; and,

The European CCO / CDO Task Force recommends that the following guidelines should be covered in the OM, either in Part A, B or C, regarding CDO operations\*:

- The challenges that crews must consider before commencing the descent, and for which airlines should have guidelines for, are:
  - Most common landing runway(s) and expected track miles;
  - Probable shortcuts or extensions (vectoring) to the lateral flight path;
  - Publication of DTG on STAR Chart;
  - Provision or not of DTG from ATC. Pilots should ask for DTG if they do not receive it;
  - ATC speed restrictions other than those planned;
  - The use of speed control correctly and with anticipation, to reduce unnecessary vectoring to reduce the track miles, or unnecessary use of speed brake or high lift devices;

- A forecast of winds and weather affecting the descent path;
- Impacts of actual Gross Weight (GW) that may be different from the GW in the FMC. The aircraft drag may also be slightly different from the FMC database drag;
- How CDO is measured at the airport or by ANSP - to ensure attention is focused on minimising noise disturbance / fuel / emissions, the airport's monitoring systems should be included in the information to crews; and,
- Whenever the monitoring of CDO performance differs from the harmonised criteria recommended by the European CCO / CDO Task Force this information should be provided to crews through its inclusion in the OM.

■ When this information is yet to be inserted in the OM, the release of company NOTAMS detailing such CDO information is considered a good practice;

■ ToD calculation - starting descent before or after the optimum/FMS ToD should be avoided where possible;

■ Descent profile management, including the preferred descent mode. When other descent modes may be used to accommodate CDOs, the relevant level restrictions, ATC restrictions and requests should also be defined. The Rate of Descent (RoD) restrictions to comply with safety recommendations to avoid level busts and Traffic Resolutions should be taken into account when describing CDO Pilot techniques;

■ Management of the Navigation Database - there are specific arrival routes for which it is not allowed to edit or modify waypoints by manual entry to the database (for departures, arrivals or approaches). User-defined data may be entered and used only under defined conditions;

■ Altitude awareness - altitude awareness is achieved by the active attention of the Flight Crew. This awareness with associated continuous monitoring is the primary means of ensuring that cleared altitudes are adhered to and clearances not infringed. The SOP mandates altitude checks that confirm altitude awareness, and also mandates vertical speeds to be flown to reduce closure rates;

■ Climb profile management, including the preferred climb mode. When other modes may be utilised to accommodate CCOs, the relevant level restrictions, ATC restrictions and requests should also be defined. The Rate of Climb (RoC) restrictions to comply with safety recommendations to avoid level busts and Traffic Resolutions should be taken into account when describing CCO Pilot techniques. Aircraft performance must be closely monitored when using V/S (Vertical Speed), especially at high altitudes;

■ Low Drag Approach (LDA) - the purpose of the Low Drag Approach is to reduce the environmental impact of the aircraft while improving passenger comfort and reducing overall fuel burn. Subject to ATC, crews should plan for a LDA. Detailed SOPs on LDAs should be provided to Flight Crew tailored to their company policy;

■ If ATC requires an early descent, either a managed mode (flight profile calculated by the FMS) should be selected (which would guide the aircraft down at a lower vertical speed), or a manual mode should be used to create a shallower descent (the Pilot may use a minimum V/S of -500 ft/min). This would allow the aircraft to converge on the optimum descent path without having to level-off;

■ If ATC delays the descent beyond ToD, the crew should anticipate a high-energy scenario and consider starting to reduce speed towards minimum clean speed (with ATC's permission). When cleared to descend, the Flight Crew should select a managed mode that will take the aircraft to the optimum profile with managed speed active; and,

■ Phraseology - airlines should include information about where to expect different phraseology from ATCOs, especially regarding Amendment 7A implementation<sup>25</sup>.

<sup>25</sup>\*Local deviations from these practices may be necessary under certain conditions.

The following figures show examples from European airlines that describe how airlines address CDO in their current OM or other documentation. These may be considered as examples of good practice:

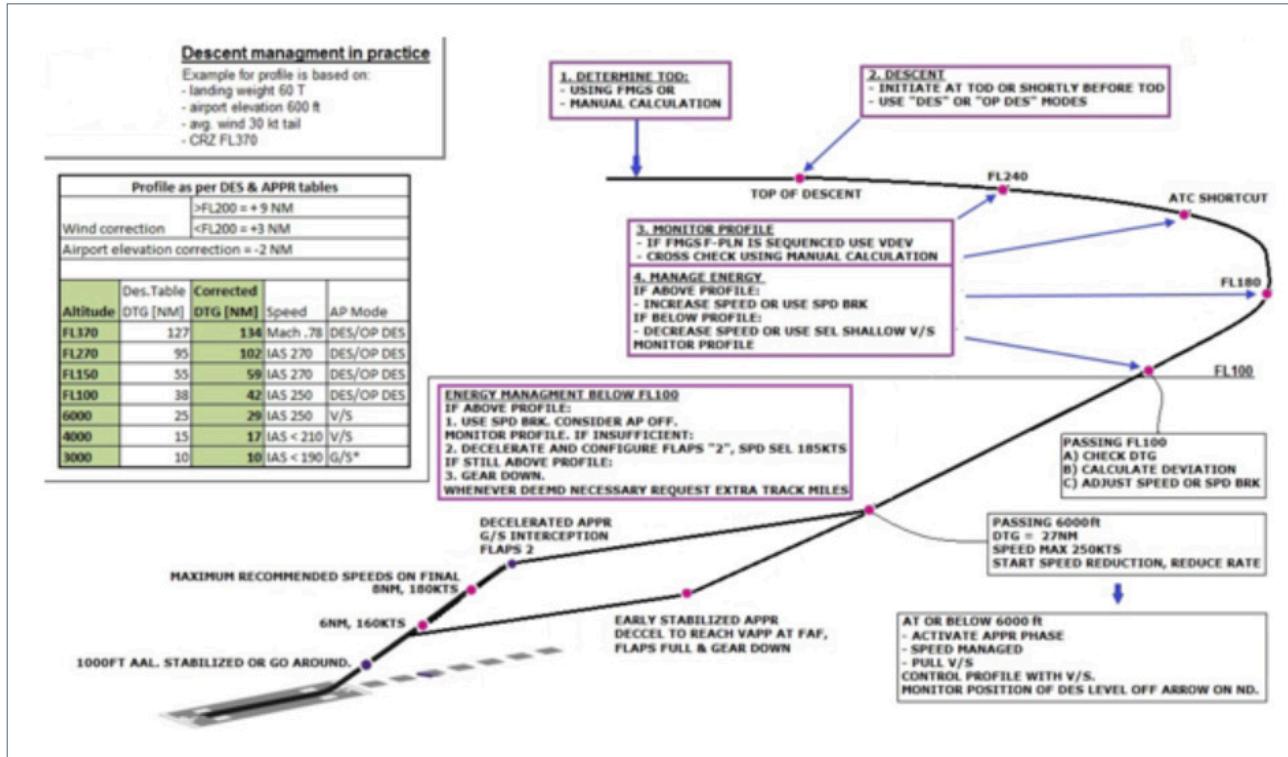


Figure 42: One airline's guidance on descent management

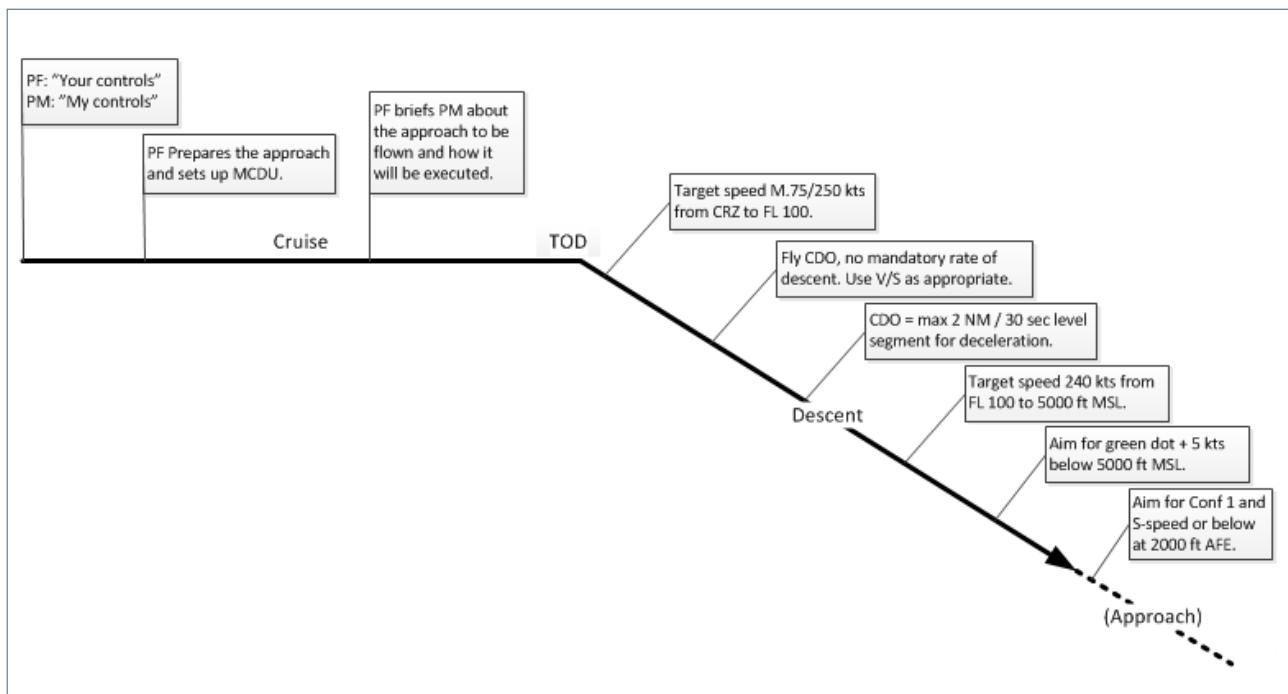


Figure 43: Example of CDO guidance from an airline.

- DESCENT (USE MANAGED SPEED (FLY AT ECON SPEED))

The descent and approach phases of flight represent the flight crew's final opportunities to reduce fuel consumption during flight. By carefully planning the airplane's descent and appropriately using drag and high lift devices, the flight crew can ensure a safe landing while saving fuel.

- Start the descent at the top of descent point.
- Plan the descent carefully.
- Fly the ECON speed.
- Use idle thrust for descents.
- Avoid flying extended periods at low altitudes.
- Configure flaps and gear for landing at the optimal time.
- Use the most appropriate final flaps setting for landing.



Figure 44: Excerpts from an Airline's A330 / A340 OM

## Descent Guidelines

### Planning:

1. Make /Update a fix page circle to cross-check FMC TOD. (3xALT+5to10NM).
2. Check for possible shortcuts to the FMC lateral path (visual, vectors, DCT, other rwy?)
3. Adjust a WPT altitude if needed to **make the TOD suitable for those possible shortcuts**.  
The goal is that if the shortcut is given, you are already on path at ECON Speed.
4. Adjust further if ATC reduced speed is very likely. ATC Speed on descent: Insert in FMC.
5. Insert the latest update of Descent Forecast Winds. Normally plan for speed 260 KTS.
6. Let your descent planning be part of the approach briefing, as needed.

### During Descent:

- Start descent at TOD in VNAV PATH.
- Adjust path when conditions change (RWY change, vectors etc) to intercept idle-thrust path for the new set of conditions. Increase speed (high) or add thrust (low) as needed.
- Insert those changes into the FMC, including ATC Speed for correct VNAV Path.
- On ATC stepped-down descents such as inbound London reset FMC CRZ ALT as needed.
- If ATC gives a reduced speed on descent, ask if MAX altitudes can be disregarded if needed.

Figure 45: Descent guidelines in an airline's fuel and cost saving guidelines



# APPENDIX K: FLIGHT CREW TRAINING

## **KEY MESSAGE**

**The European CCO / CDO Task Force recommends that Aircraft Operators develop specific training material on CCO / CDO to increase awareness and proactive management of flights. The European CCO / CDO Task Force will develop a Computer-Based Training (CBT) and associated visual aids to support Aircraft Operator refresher training materials.**

**The Task Force also recommends that CCO / CDO should be included as a competence in initial line and recurrent training together with the inclusion of specific CCO / CDO training practices in their Operations Manuals. This will ensure that Flight Crews are continuously trained on the best flying techniques for the specific airplane they fly.**

**The Task Force is also proposing specific updates to the training objectives for private and commercial licenses in the relevant Flight Crew Licensing (FCL) Regulations or ATO Training Manuals.**

## **K1: General principles**

CCO and CDO are aircraft operating techniques enabled by airspace design, instrument procedure design and facilitated by ATC. As operating techniques, it is essential that Flight Crew are properly trained on the different techniques that can be applied, depending on the traffic circumstances, different operational scenarios and tactical instructions received from ATC. Although both CCOs and CDOs may both provide performance benefits, Flight Crew training material is mostly focused on CDO as the descent phase is the phase that may be subject to many different situations that may require the use of specific pilot techniques. In addition, with the ATC CONOPS usually enabling a CCO to the extent possible (although this may change in the future – see appendix H), the Task Force has demonstrated that the level of fuel burn / emissions benefits available in the climb phase is only approximately one-tenth of those available from optimising the descent phase. This appendix therefore proposes to concentrate primarily on recommendations for Flight Crew training on CDO.

When ATC conditions allow, and in order for airlines / crews to achieve a high rate of CDO compliance, understanding the benefits associated with a CDO (environmental impact, passenger comfort and fuel burn reduction) is vital. So the first step in having Flight Crews that try to perform their best in all conditions, even if these conditions are not optimal for carrying out a CCO / CDO, is to have a training system that embeds techniques in the training program (initial and recurrent) and continually re-inforce the importance of applying these techniques in all operations.

This holds true for both the theoretical background (e.g. on aircraft performance and CDO itself) and practical operational aspects. For airlines / Flight Crews to successfully enhance the efficiency of the vertical profiles, theory needs to be complemented with practice in order to increase awareness and proactive management of the flight.

The Task Force agrees that classroom exercises and reading prescribed materials alone is not enough and unlikely to be the right approach to boosting the Flight Crews' CDO performance. Specific training with clear practical examples can teach more effectively than theory. It is a great help if management – airlines' and regulators' – put the right emphasis on training. Not only will resources be then made available, but the commitment shown at high levels in the airline and the regulator will convince those who need to change their attitude.

The Task Force is aware of the fact that practical simulator pilot training is already very demanding and many different scenarios need to be practiced in a limited amount of time, with time available in simulators being a scarce resource. This is why the following recommendations are meant to integrate CCO / CDO as a competency in training, not just as stand-alone exercise in the simulator with integrated CCO / CDO flying techniques.

Recommendations in this Appendix try to cover both initial and recurrent training. For the initial Flight Crew training, the recommendations are for the Regulatory Authorities to include the prescribed CCO / CDO training in the learning objectives for all Flight Crew licenses and class / type rating training. **This can be achieved by inserting them into the FCL Licensing Regulations, which should be done by the regulators, or by the Aviation Training Organisations (ATOs) when developing the training programmes of each course, so they include these learning objectives as best training practices.**

At the time of delivering this Action Plan, the Task Force has made a proposal to EASA to include more specific Flight Crew training learning objectives on CCO / CDO in the relevant regulations. EASA has taken note of this proposal and a decision is pending if it can be included in the EASA Environmental Strategy, which will be developed in 2020.

**It should be noted that any proposal to modify the regulatory requirements or training course syllabi is made as a way forward or 'tool box', offering ideas for possible ways of implementation. It is for the responsible people to implement these proposals the way they best consider appropriate, following their own rulemaking / course approval processes.**

For recurrent training, recommendations are for the airlines to include specific CCO / CDO training practices in their Operations Manuals, so that Flight Crews are continuously trained on the best flying techniques for the specific airplane they fly.

## K2: Initial Training

In order to have CDO included in initial training for ALL Pilots, the regulator should include the following learning objectives in the respective section of the regulation(s) – note that text in bold below represents new proposals outside of current regulatory text:

### 1. For private licenses:

- a. Theoretical training: OPERATIONAL PROCEDURES. General Operation of aircraft: ICAO. Annex 6, General requirements:
  - i. **Noise abatement;**
  - ii. **Noise abatement procedures;**
  - iii. **Influence of the flight procedure (departure, cruise, descent and approach) on noise and fuel efficiency (CCO / CDO procedures);**
- b. Practical training: Each of the exercises in the Syllabus of flight instruction involves the need for the applicant to be aware of the good airmanship and look-out, which should be emphasised at all phases of flight, especially during:
  - i. Climbing: entry, maintaining the normal and max rate climb and levelling off, **Continuous Climb Operations;**
  - ii. levelling off at selected altitudes;
  - iii. Descending: glide, powered and cruise descent (including effect of power and air speed), **Continuous Descent Operations.**

### 2. For Commercial licenses:

- a. Theoretical training.
  - i. Name the conditions that must be adhered to when two aircraft are cleared to maintain a specified vertical separation between them during climb or descent. **State CCO and CDO definitions** Source: ICAO Doc 4444, Chapter 5, 5.3.4 Vertical separation during climb or descent
  - ii. Environmental requirements:

- **Reference to global and EU Environmental Regulations**
- **Effects of non-optimal cruising levels**
- **CCO / CDO and Pilot techniques:**
  - **Closed Paths and restriction compliance**
  - **Speed management**
  - **Vertical speed management**
- **Piloting techniques for:**
  - **Path stretching**
  - **Open Paths**
  - **Vectoring**
- **Importance of DTG**

b. Practical training: at the proper flying instruction phase:

- i. Exercises up to the instrument rating skill test comprise procedures and manoeuvres for IFR operation under normal, abnormal and emergency conditions covering at least, among others:
  - SIDs and arrivals, **with the application of proper CCO and CDO techniques.**

**3. For the MPL license:**

- a. List of competency elements and performance criteria during climb should include how to select and maintain the appropriate climb speed or rate of climb, **according to CCO good practices;**
- b. List of competency elements and performance criteria during descent should include the initiation and management of the descent, **according to CDO good practices.**

**4. For the Class / Type Rating training:**

- a. Type Rating Courses content should cover:
  - i. Aircraft energy management:
    - Speed management: economy speed vs selected;
    - ATC tactical manoeuvring: manage automation modes to optimise descent.
  - ii. Piloting Techniques:
    - Starts descent according to ATC clearance or optimum descent point;
    - Selects optimum speed and descent rate;
    - Adjusts speed to existing environmental conditions;
    - Recognises the need to adjust the descent path;
    - Adjusts the flight path as required;
    - Utilises all means of FMS descent information.
  - iii. Closed Paths and compliance with published constraints and the use of FMS, speed management;
  - iv. Piloting techniques for:
    - Path stretching;
    - Open Paths;
    - Vectoring;
  - v. Importance of DTG

## K3: Recurrent training

Including CCO / CDO as a competence in the Flight Crew Line Training is held to be a good practice for keeping Crews fully appraised of the importance of using the most efficient flying techniques throughout a flight.

Having CDO as a competence ensures that CDO techniques are taught and that the Pilot undergoing training will demonstrate proficiency in line checks before the final sign-off to line operation can take place. It instils a CDO mentality from day one of their airline training.

This has been observed to be very useful for Pilots - especially those who come from backgrounds where CDO is not traditionally considered to be a required flying technique. But if it is to be considered essential, Flight Crews would always attempt to conduct a CDO (ATC, Approach type and SOPs permitting). It has been previously demonstrated that, where CDO-trained Flight Crew have moved to another airline, this airline has subsequently experienced an improvement in CDO.

It should be noted that simulator training costs may incur significant costs to Operators. In an ideal world, Flight Crew refresher training should include both theory and practical training. Flight Crew refresher training usually includes many mandatory exercises that are required by EASA and the simulator schedule may already be full. In these cases, refresher training may be supported by theory and other visual aids such as CBT, video or animations as alternate resources to pass on clear messages.

The European CCO / CDO Task Force considers that airline refresher training courses in the Operation Manual, Part D, should, at the very minimum, include the following items regarding CDO:

■ **Aircraft energy management:**

- i. Speed management: economy speed vs selected
- ii. ATC tactical manoeuvring
- iii. Factors that influence optimised vertical profile
- iv. Rules of thumb for descent:
  - ToD in nm = altitude (in 000's ft) x 3 + margin
  - 1 knot speed reduction = 1 kg fuel saved, but 3 seconds more time flown

■ **Good Practice Piloting Techniques:**

- i. Closed Path restriction compliance
- ii. Speed management
- iii. Vertical speed management
- iv. Piloting techniques for:
  - Path stretching
  - Open Paths
  - Vectoring
- v. Importance of DTG

■ **ATC tactical interventions:**

- i. Factors taken into account by ATC for tactical management of aircraft
  - Speed Control
  - Vectoring
  - Departures versus arrivals
- ii. What ATC expect from Flight Crew to be able to facilitate CCO / CDO

These messages may be passed on ideally in theory and practical training. Should simulator slots not be available, the European CCO / CDO Task Force will be developing a CBT and associated visual aids to support Aircraft Operator refresher training materials.

The above-proposed minimum structure for an airline refresher training course will be updated once there is a clear proposed structure for the CBT as proposed by Task Force Pilot representatives.

Some examples from industry have also demonstrated the benefits of having specific training policies e.g.:

- Training and using specially trained Pilots, acting as Fuel Coaches. The purpose is for these Fuel Coaches to share good practice during normal flight operations with other colleagues, and this includes aspects related to CDO;
- Developing training material that focuses specifically on the management of the profile in non-standard situations, tailored for the destinations flown, especially the home base;
- Developing a web-based training as a follow up for the different situations experienced with their home base projects, such as the HTO (High Transition Operations) project (see Appendix Q). These may take a holistic view or zoom in on non-standard situations that have been experienced over time;
- Using performance monitoring tools to update Standard Operating Procedures, in order to align them with identified good practices; and,
- Dissemination of CDO performance information through dedicated regular training Newsletters.

Some airline examples that may be considered as good practices are detailed below:

**FlySmart Bulletin #10**

Category: Descent  
Subject: Continuous Descent Operations  
Edition 1, Date 2014-03-12, Author:

**Rationale**

Increased focus on Continuous Descent Operations (CDO) is observed in the world and there is a need for airlines to be adaptive to requirements and needs by other stakeholders (e.g. airports, Air Navigation Service Providers (ANSPs), airport neighbours) and society in general. This requires the concept to be thoroughly explained, to give background information and also how this should be linked to operational recommendations. By conducting CDO many benefits can be drawn, including increased flight safety, lowered noise and emissions.

**Background**

It is fair to say that the concept of continuous decent operations is not new; it has been in place for many years but not strongly linked to a definition or a concept. For pilots to descend with the engines at idle thrust is usually an integrated part of any basic pilot training. For many years this concept has been adopted, especially in low-density traffic environments where aircraft typically have been able to operate unconstrained without interference from Air Traffic Control (ATC). There are no requirements for unique equipment onboard the aircraft to conduct a continuous descent. Basic rule of thumbs adopted by pilots work generally quite well and the more skilled they are, the better the overall result will be.



Figure 1: Continuous Descent Concept.

There has been a linkage between this concept of operation and environmental aspects over the years, since there are advantages with this concept in terms of lowered noise

Figure 46: Example on theoretical CDO guidance material.

<b>TAKEOFF / CLIMB</b>																
19	Takeoff Procedures															
20	Noise Abatement Procedures															
21	Departure Procedures															
22	Climb Procedures															
<b>CRUISE</b>																
23	Navigation															
24	Optimum Flight Level															
25	Fuel Management															
26	Systems Monitoring															
27	Meteo															
28	Arrival Preparation															
29	Alternate Preparation															
30	Arrival Briefing															
<b>DESCENT</b>																
31	Descent Procedures															
32	Continuous Descent Approach															

Figure 47: Example of CDO included in the training syllabus for Flight Crew Conversion training and checking AND Flight Crew Refresher Training

		INITIAL LINE TRAINING STUDENT COMPETENCY CHECKLIST (COMMAND UPGRADE)				FORM REF FCILT - CU Issue Date 1 <sup>st</sup> Mar 2018
CANDIDATE NAME:		CREWCODE:				
FUNCTION OR PROCEDURE		Instr. Initial	FUNCTION OR PROCEDURE		Instr. Initial	
1.	PLANNING		8.	APPROACH		
1.1	CRM	PA1	8.1	NON-PRECISION APP USING VNAV	PA2	
1.2	PUNCTUALITY	PA1	8.2	NON-PRECISION APP USING V/S	PA2	
1.3	ATTIRE / DEPORTMENT	PA1	8.3	MANUAL APPROACH (4nm)	PA2	
1.4	LIASON WITH CABIN CREW	PA2	8.4	LOW DRAG APPROACH	PA2	
1.5	LIASON WITH CREW CONTROL / OPS	PA2	8.5	LOW DRAG APPROACH	PA2	
1.6	INTERPRETATION OF WX, NOTAMS ETC	PA2	8.6	CATII/IIIA APPROACH	PA2	
1.7	FUEL PLAN AND CALCULATION	PA2	8.7	CATII/IIIA APPROACH	PA2	
1.8	DISPATCH WITH FLIGHT PLAN FUEL	PA2	8.8	CATII/IIIA APPROACH	PA2	
2.	AIRCRAFT PRE-FLIGHT		8.9	MONITORED CAT1	PA2	
2.1	AIRCRAFT DOCUMENTATION	PA1	8.10	MONITORED NPA	PA2	
2.2	FLIGHT PREPARATION AND BRIEFINGS	PA1	8.11	VISUAL APPROACH	PA2	
2.3	OPT CALCULATION	PA1	9.	LANDING AND TAXI		
2.4	TECHNICAL LOG	PA2	9.1	APPROACH AND LANDING	PA2	
2.5	LIASON WITH GROUNDCREW / ATC ETC	PA2	9.2	SINGLE ENGINE TAXI	PA3	
2.6	LOADSHEET	PA2	9.3	SHUTDOWN CHECKLIST	PA1	
2.7	TIME MANAGEMENT	PA2	10.	DISCUSSION ITEMS		
2.8	DISPATCH MANAGEMENT	PA3	10.1	GO-AROUND	PA1	
2.9	PA's	PA1	10.2	HIGH ENERGY APPROACH PREVENTION	PA1	
3.	PUSH START AND TAXI		10.3	ROTATION / TAILSTRIKE AVOIDANCE	PA1	
3.1	PUSHBACK AND COMMUNICATIONS	PA1	10.4	PILOT INCAPACITATION	PA1	
3.2	RUNWAY SECURITY	PA1	10.5	HIJACK	PA1	
3.3	TAXING	PA3	10.6	BOMB ALERT	PA1	
4.	TAKE-OFF AND CLIMB		10.7	MEDICAL EMERGENCY	PA1	
4.1	TAKE OFF AND INITIAL CLIMB	PA1	10.8	DEPRESSURISATION	PA2	
4.2	SID COMPLIANCE	PA1	10.9	EMERGENCY DESCENT	PA2	
4.3	ALTITUDE AWARENESS	PA1	10.10	SNOWTAMs	PA2	
4.4	NO ENGINE BLEED TAKE-OFF	PA2	10.11	LOSS OF RADIO COMMUNICATION	PA2	
5.	CRUISE		10.12	DRIFTDOWN PROCEDURE	PA2	
5.1	R/T PROFICIENCY	PA1	10.13	DE-ICING PROCEDURES	PA2	
5.2	DESCENT PLANNING	PA1	10.14	SAFA INSPECTIONS	PA2	
5.3	APPROACH AND LANDING BRIEF	PA1	10.15	CFIT/EGPWS AWARENESS	PA2	
5.4	USE OF NAV AIDS	PA1	10.16	RTOW CALCULATION	PA2	
5.5	NAVIGATION AND USE OF CHARTS	PA2	10.17	PLOC	PA1	
5.6	USE OF WX RADAR	PA3	11.	MANAGEMENT ABILITY		
6.	DESCENT AND APPROACH		11.1	APTITUDE	PA1	
6.1	STAR	PA1	11.2	INITIATIVE	PA1	
6.2	ALTIMETER SETTING	PA1	11.3	WORK RATE	PA1	
6.3	USE OF FMC	PA2	11.4	COMMERCIAL ATTITUDE	PA1	
6.4	SITUATION AWARENESS	PA2	11.5	INTERPERSONAL SKILLS	PA2	
6.5	PROFILE AWARENESS	PA2	11.6	COMMUNICATION	PA2	
6.6	SPEED CONTROL	PA2	11.7	LEADERSHIP	PA3	
6.7	CDA	PA2	11.8	ANTICIPATION	PA3	
7.	IF New Home Base is Restricted		11.9	PROBLEM SOLVING	PA3	
7.1	Appr Restricted Base if applicable	PA3	12.	KNOWLEDGE OF:		
7.2	Appr Restricted Base if applicable	PA3	12.1	SOPs	PA1	
7.3	Appr Restricted Base if applicable	PA3	12.2	FCIs	PA1	
7.4	Appr Restricted Base if applicable	PA3	12.3	AIR LAW	PA2	
13.	LICENCE		12.4	IFR PROCEDURES	PA2	
13.1	ATPL		12.5	OPS MANUAL PART A	PA2	

Figure 48: Example of CDA requirements in the Flight Crew Initial Line Training

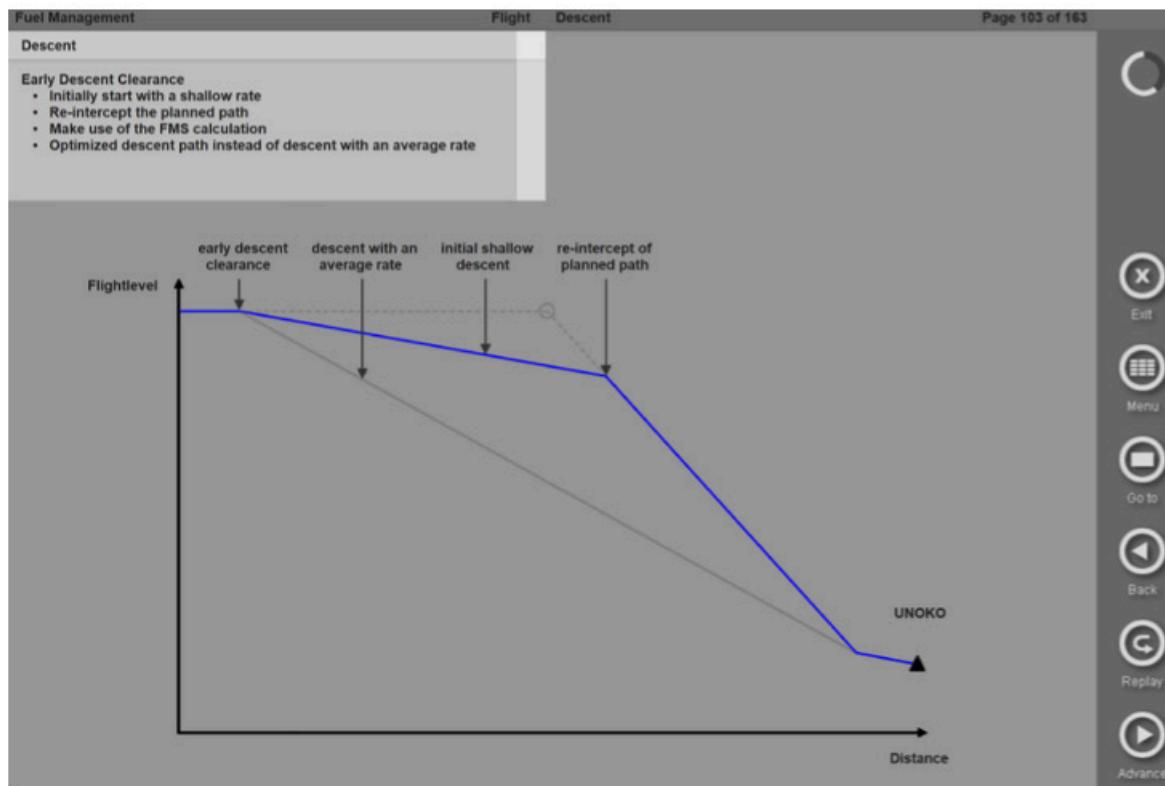


Figure 49: Excerpt from an airline CBT on fuel management



## APPENDIX L: AIRLINE PERFORMANCE MONITORING AND FLIGHT CREW FEEDBACK

### **KEY MESSAGE**

**The European CCO / CDO Task Force has demonstrated that CDO performance monitoring breeds a performance improvement. The Task Force therefore recommends that all Aircraft Operators should monitor CCO / CDO performance and provide performance feedback to Flight Crews so that areas where CDO performance can be improved can be highlighted so that Operators can benefit from reduced fuel burn and CO2 emissions. This can be done with ANSP data or performance data received from airports.**

**One way in which an Aircraft Operator can monitor CDO performance is through Flight Data Monitoring (FDM) / Quick Access Recorder (QAR) data, where such data is available. This will enable Operators to draw their own conclusions about their current CDO performance and identify what factors may enhance their operations.**

**Following performance measurement, factors to consider in enhancing CDO performance may be a more optimised airspace organisation, enhanced ATC facilitation, or the impact of training material or SOPs described in the Aircraft Operators manuals.**

Appendix C explains why the European CCO / CDO Task Force considers that performance monitoring of CCO / CDO and giving feedback to the Flight Crew involved are one of the best enablers of improved CDO performance. NATS have clearly demonstrated the benefits of CDO from the ANSP side while Wizz Air have demonstrated the performance improvement gained from monitoring performance from the airline side (for both case studies see Appendix Q).

Whereas appendix B concerns performance monitoring and Flight Crew feedback in general, this appendix specifically concerns proposals to Aircraft Operators to undertake performance monitoring and Flight Crew feedback. The Task Force considers that this is the best way to get buy-in from Operators to demonstrate just how performance can vary between operators, airports and individual Pilots so that dedicated Pilot trainings and Operator policies can be developed to harness some of the fuel emission savings that are available.

Experience has shown that Flight Crew only have limited control / influence over CCO whilst the benefits from optimised CCO are much smaller than optimised CDO. Therefore, the Task Force recommends that if performance monitoring for efficiency purposes is undertaken by an Aircraft Operator, the focus should be on the descent phase and CDO.

Although performance monitoring can be supported by CDO performance feedback from individual airport operators, this Action Plan promotes the measurement of CDO performance by all airlines and airline groups as an enabler to improved CDO performance and achieve the resulting fuel / emissions savings.

Data has shown that, at a single airport, different aircraft operators will experience a range of CDO performance levels. In addition, individual airlines may experience a range of CDO performance results, depending upon the aircraft type flown or the time that each flight is flown. However, when a single flight, flown with the same aircraft type, is flown to the destination airport, at the same time every day and experiences a range of CDO performance results, there is probably room to improve performance. This is where performance monitoring and feedback to Pilots on performance data may help to generate an overall performance improvement.

It may also be possible to gain the benefits of local knowledge, especially by comparing the CDO performance of local-

ly-based carriers with those of foreign carriers. Based on these analyses, ATC can identify those factors that increase the benefits of the locally based carriers in order to share such good practices with other airlines. This is one of the main objectives of the performance dashboard detailed in Appendix C.

Despite this, as demonstrated in Appendix A2, the Task Force's airline questionnaire concluded that:

- Only 23% of airlines measure the CDO performance of individual flights;
- Only 16% measure the CDO performance of individual Flight Crews; and,
- Only 21% and 11% respectively pass on the results of the performance monitoring to the individual flights or Flight Crews.

Airlines that do monitor CDO performance are generally those that have the best CDO performance and are usually more knowledgeable about how their actions can reduce fuel burn and emissions reductions.

At a recent a Pilot forum meeting, it could be seen that different Pilots held very contrasting views on CDO. These ranged from: "There are significant benefits available from CDO." to: "CDO can provide no benefits in my home air-space." and even "What is CDO?"

While training can raise awareness of the constraining factors to optimised CDO and possible mitigation methods, performance monitoring and performance feedback to individual Pilots provides the evidence to demonstrate directly to the Pilots themselves that CDO performance can be improved.

Airlines can use aircraft-derived data for CDO monitoring and data can be presented in a myriad of different ways. One such example from an airline that measures CDO performance is to benchmark fuel burn for every flight from a point 200nm from the destination airport. While this may not be useful for a network performance comparison, by comparing each flight on a per-flight basis for those airports where the airline has a base, this can provide useful information about which procedures are more environmentally optimised than others. It can also help the airline to and identify other arrival routes where fuel savings could be made.

Furthermore, CDO performance figures should be fed back to each Pilot at each base - in an anonymous way so that each Pilot only sees their own performance but also sees where they rank, compared to other Pilots at that base. This is an extremely useful way of generating performance improvements, as each Pilot is conscious as to where they sit in a ranking of their peers and will naturally strive for performance improvement. This may also help an airline to identify any outliers in performance and see where particular training or other support could be focused.

It should be noted, however, that while CDO performance measurement is recommended by the Task Force as a very important action to take, it should not be used on a personal performance basis: i.e. no economic or other incentives should be introduced; rather it is vital that a just, no-blame culture be encouraged.

The Task Force also recommends that every Operator should include CDO in performance monitoring through FDM / QAR data, where such data is available. This will enable Operators to draw their own conclusions about what factors contribute to the achieved performance level: whether that is due to airspace organisation, or facilitation by ATC, or what benefits can be derived from the training and SOPs described in its manuals.

It should be noted that not all FDM data may be shared for performance measurements. Many airlines have significant union restrictions in using FDM data for performance monitoring. In some States, Germany for example, this may not be consistent with a non-punitive airline culture. In addition, for certain aviation sectors e.g. business aviation, due to the low amount of traffic on specific city pairs, and the fact that many of these aircraft are not equipped with FDM, they may rely more on a centralised performance monitoring system to feed back on their performance (see appendix C).

The airline examples below show how some airlines use vibrant and multifunctional charting possibilities to give feedback on CDO performance to their Flight Crew or to airline management. In spite of the examples shown below, it is important to remember that this kind of performance monitoring is currently undertaken by **less than a quarter** of European airlines. To provide a network performance improvement, this figure needs to be increased. The CCO / CDO performance dashboard was developed to support this recommendation.

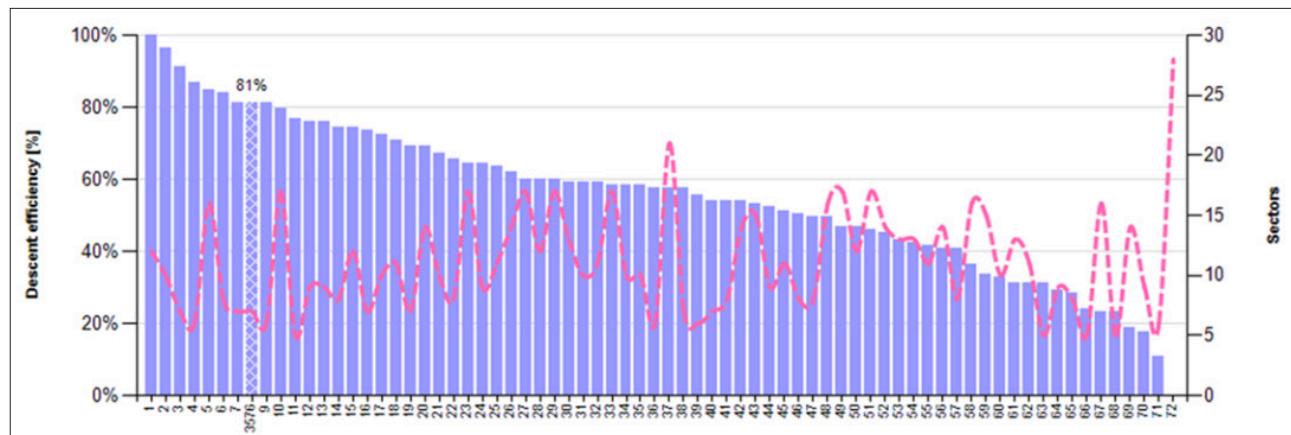


Figure 50: Example of the individual Flight Crew performance at an airline's base compared to all other Flight Crew members

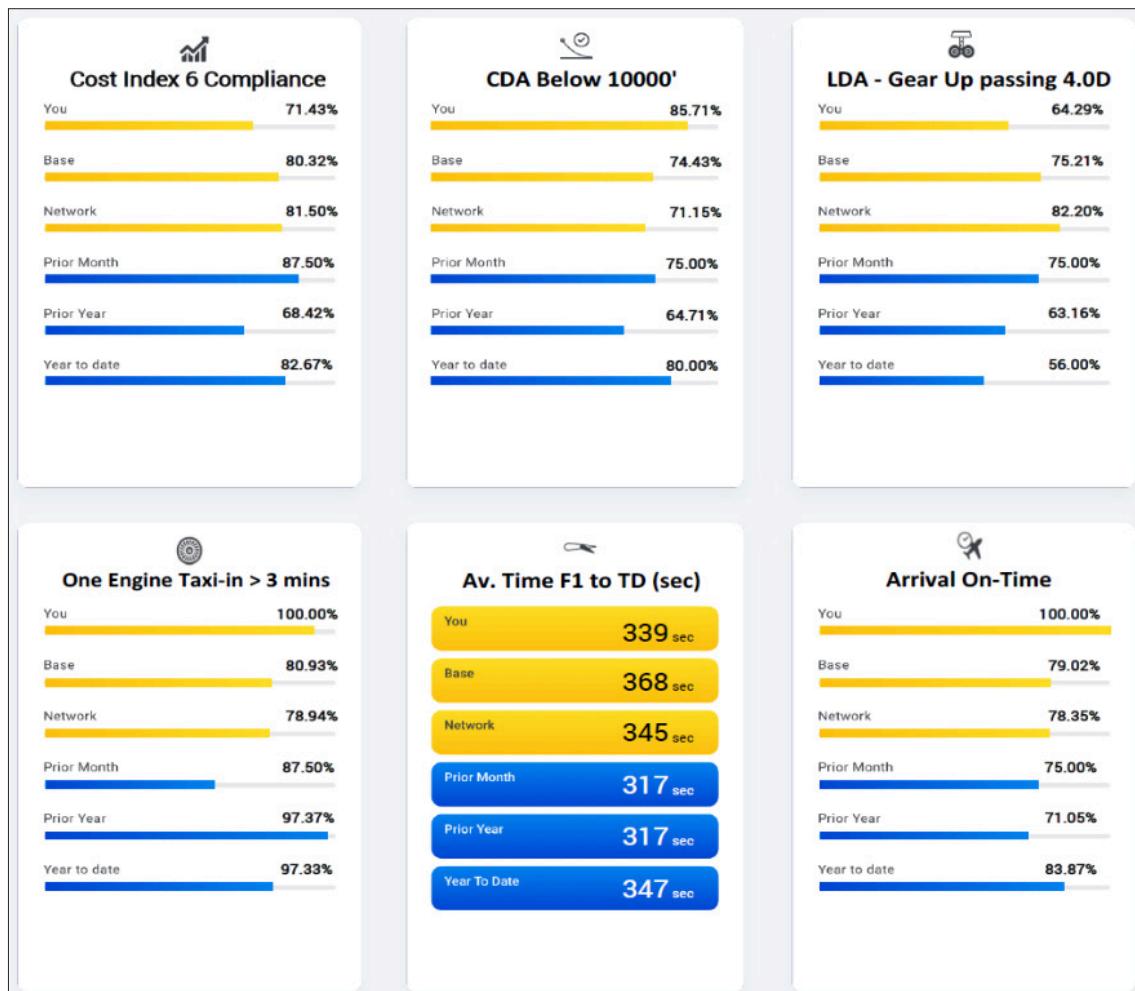


Figure 51: Example of performance feedback to Flight Crew via their individual Flight Crew performance dashboard and comparing all other Flight Crew members at the base and network

Other airlines can present data that provides feedback on performance at a cross-section of airports – in the example below (Figure 52), time in level flight is monitored versus the landing runway. Airport 1 has four runway ends, Airports 2, 3, 5 and 6 have two runway ends and airport 4 has six different runways ends. This allows the airline to identify where CDO performance improvement could be enhanced and where training could be focused.

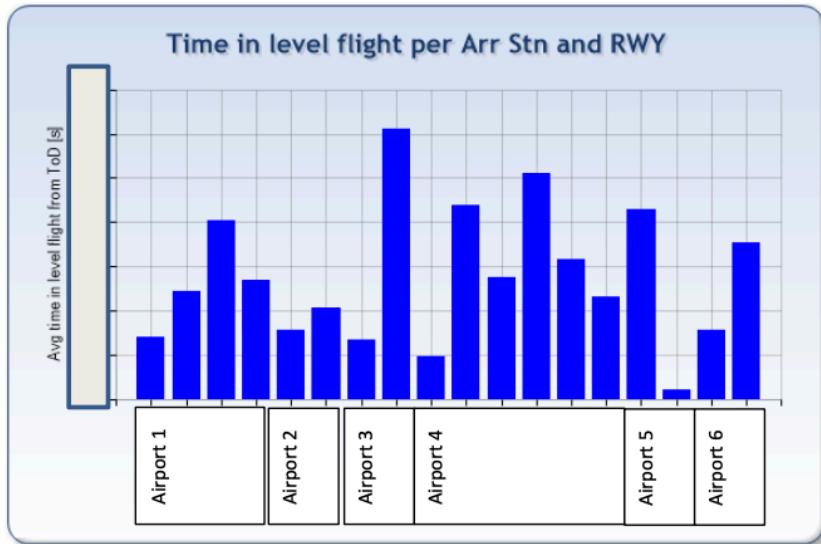


Figure 52: Example of performance feedback on time in level flight versus landing runway at different airports.

Other airlines that do not have the resources to monitor their own performance can share performance feedback with their Pilots for flights to selected airports (see Figure 53 for one example), that do measure regular CDO performance. This demonstrates how the airport may have a role to play, even if not directly responsible for either enabling CDO or flying CDO.

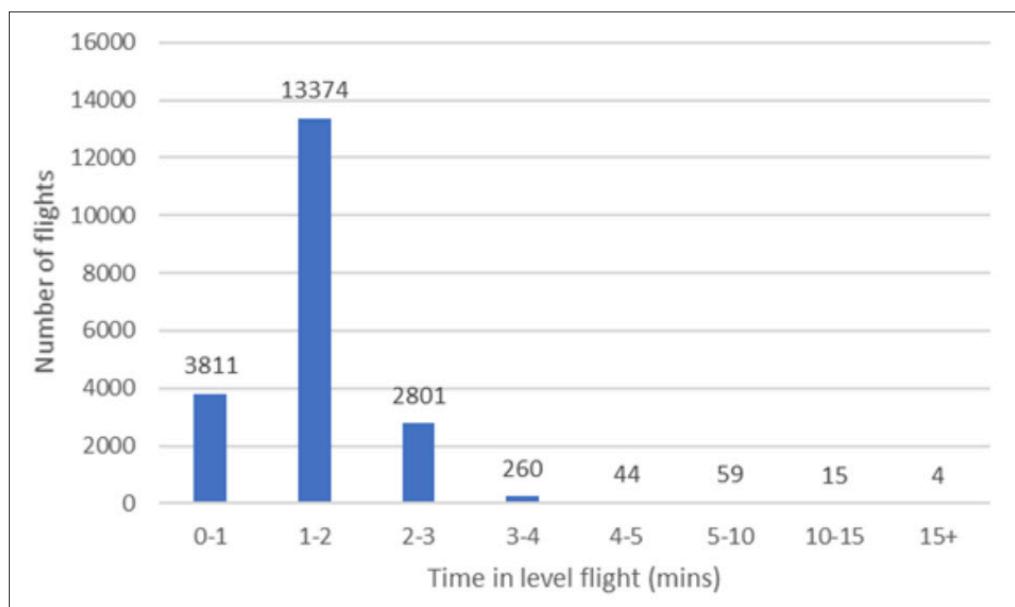


Figure 53: Example of airline CDO performance shared by one airport to one of its airlines

Airline groups also have a role to play. When a group is responsible for the performance of more than one airline, statistics can be used to compare CDO performance across the group to try to illustrate where performance could be systematically improved by each airline, at a specific airport or both. This perfectly illustrates the objective of the Task force's performance dashboard and is demonstrated in Figure 54.

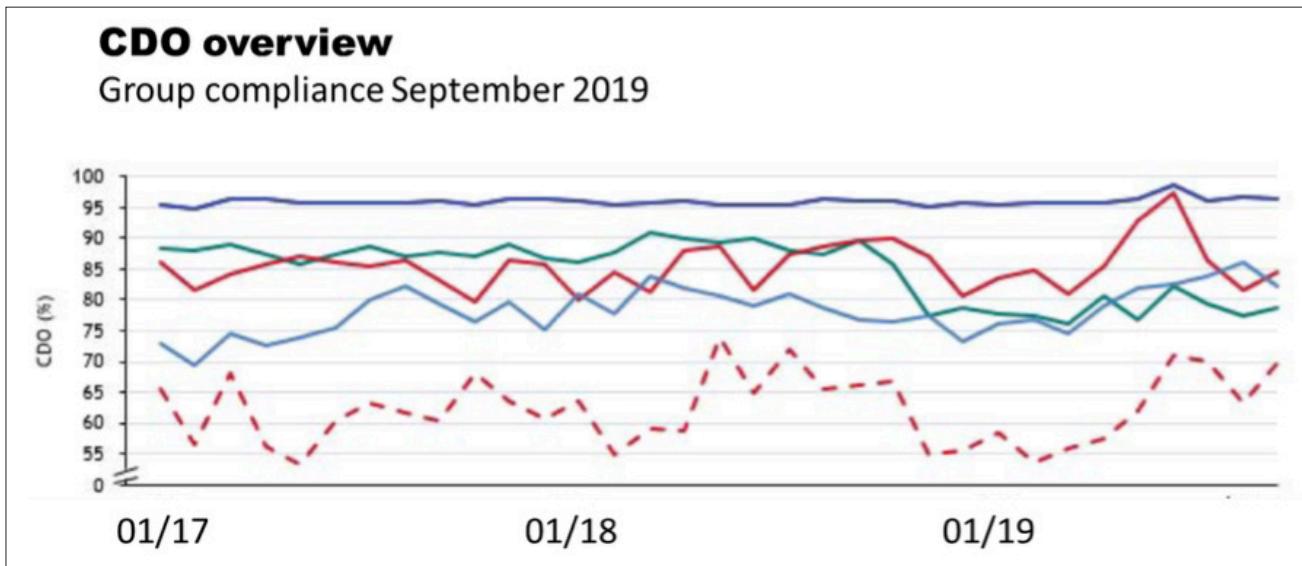


Figure 54: Example of CDO performance shared to an airline group in September 2019

Other airlines share performance data in other ways. One airline not only regularly produces newsletters to announce the latest fuel saving figures but also is collaborating, together with other airlines, with companies that have developed fuel efficiency software and use big data algorithms to calculate fuel savings from optimised operational procedures.

Some companies have even developed smartphone applications that compute possible fuel savings considering the exact flight conditions (weather, runway conditions etc.) together with details of the airlines' fuel saving SOPs. This application allows the Flight Crew to replay their flight and, if a fuel saving good practice was applicable, it then computes the achieved and potential savings to give a quality score. This 'remaining potential available from optimising the descent' can be measured for individual airports and aircraft types; see example in Figure 55.

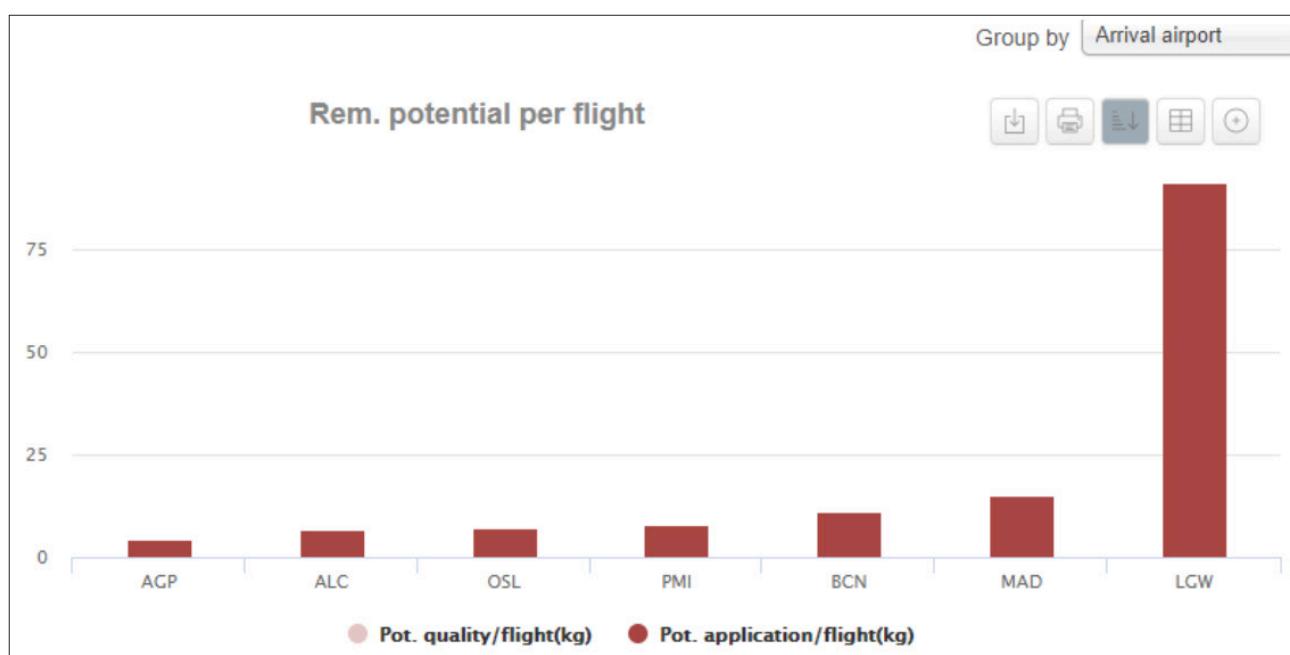


Figure 55: Example of performance monitoring on the remaining potential available from optimising the descent at different airports.

Another example may be found in Figure 56).

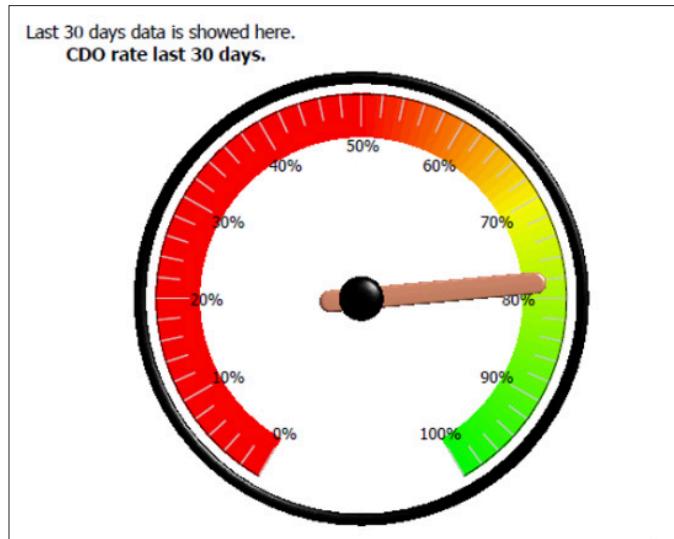


Figure 56: Example of charts developed by an airline based upon CDO performance data shared by specific airports

Another airline shares monthly statistics on CDO (Figure 57) that demonstrate the link between CDO compliance and the traffic levels.

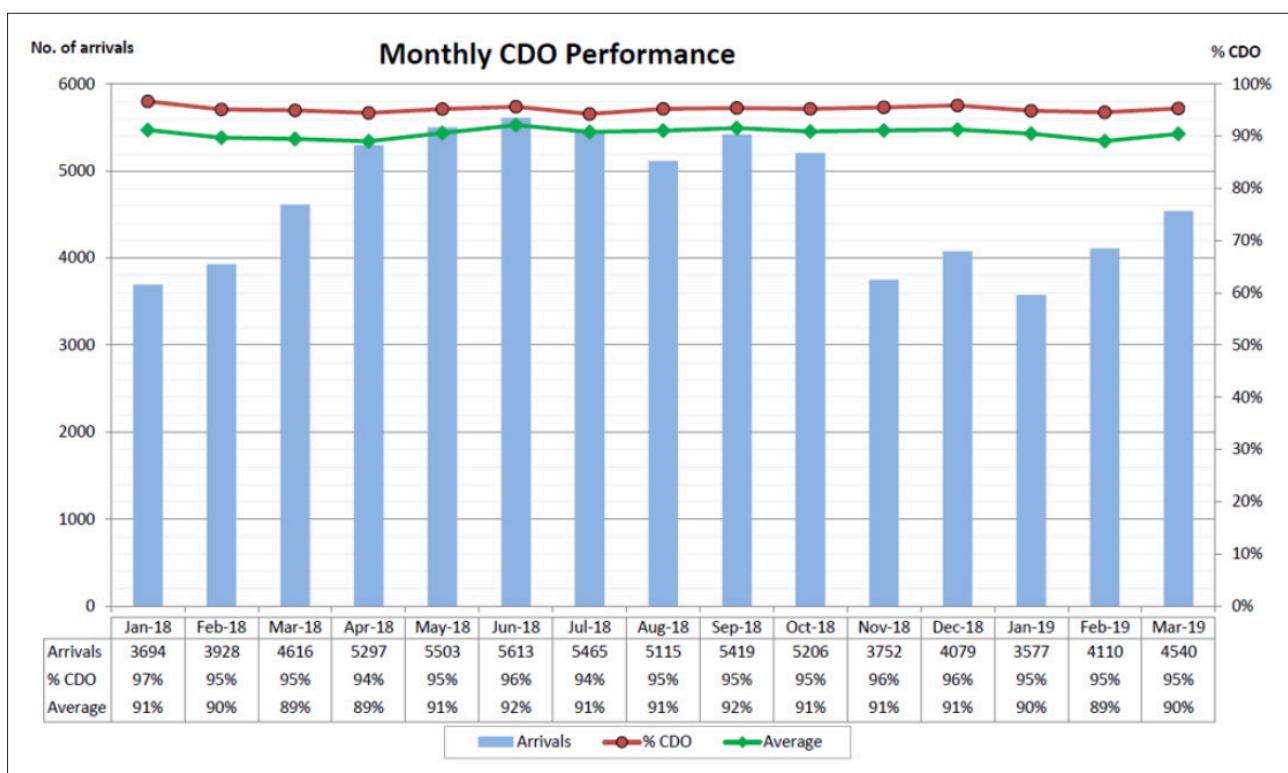


Figure 57: Example of CDO performance statistics set against monthly traffic levels

Another airline shares CDO performance data by debriefing their Flight Crews on a regular basis with information on the benefit pool available from a range of operational initiatives and the actual fuel savings achieved (see Figure 58).

FUEL EFFICIENCY INITIATIVES   2019		
	FUEL (ton)	CO2 (ton)
APU Policy (Fuel)		
APU Policy (Maintenance)		
Engine Out Taxi-in		
NADP2 (Noise Abatement Departure Procedure)		
Reduced Flap Takeoff		
Reduced Flap Landing		
Idle Reverse on Landing		
Engine Out Taxi-out		
Commander/Fueller Extra Fuel		
CDA (Continuous Descent Approach)	3.309	10.424
Alternate Selection		
Dispatcher/Ops Extra		
Route Optimization		
ZFW (Zero Fuel Weight plan vs actual)		
Airframe/Engine Drag/Aerodynamics/Wash/Paint		
Weight Reduction (EFB)		
Potable Water		
CG optimization		
<b>TOTAL</b>	<b>43.224</b>	<b>136.155</b>

Figure 58: Monthly Airline feedback on fuel efficiency initiatives

One final example relates to an airline that has developed its own way to track, measure and quantify the efficiency and fuel savings of all arrival descents between 10,000-2,000ft. The airline uses a 2.5° or greater descent profile as a reference for its measurement, using parameters that have been defined internally, using the term Energy Management Operations (EMO), which should not be confused with the industry standard CDO definition.

The analysis is achieved in four parts:

1. Determine a flight count of all arrival flights meeting the defined criterion;
2. Determine the average fuel burn for those flights;
3. Set an efficiency threshold by determining the average fuel burn of all flights with a 2.5° descent profile; and,
4. Determine the actual average fuel burn per month for all flights meeting this efficiency threshold or better e.g. 2.5° or greater descent profile.

The resulting fuel savings are the difference between #2 & #4 multiplied by #1. The results are then disseminated internally to demonstrate the level of benefits from flying optimised CDO, or via a proxy, EMO.

1	2	3	4	5	6	7	8	9	
1	Month	Total Network Arrivals	Total EMO Arrivals	% EMO Arrivals	Avrg EMO Fuel Burn (Kg)	Avrg EMO Fuel Saved (kg)	EMO Fuel Savings (Tonnes)	Co2 Savings	\$
2	JAN	1587	365.01	23	404	328.00	119.72	377.13	\$ 74,827
3	FEB	1337	280.77	21	405	327.00	91.81	289.21	\$ 57,382
4	MAR	1641	344.61	21	408	324.00	111.65	351.71	\$ 69,784
5	APR	1599	383.76	24	408	324.00	124.34	391.67	\$ 77,711
6	MAY	1634	359.48	22	414	318.00	114.31	360.09	\$ 71,447
7	JUN	1562	406.12	26	419	313.00	127.12	400.41	\$ 79,447
8	JUL	1609	418.34	26	412	320.00	133.87	421.69	\$ 83,668
9	AUG	1639	409.75	25	407	325.00	133.17	419.48	\$ 83,230
10	SEP	1624	487.2	30	411	321.00	156.39	492.63	\$ 97,745
11	OCT	1616	404	25	408	324.00	130.90	412.32	\$ 81,810
12	NOV	1746	401.58	23	400	332.00	133.32	419.97	\$ 83,328
13	DEC	1625	357.5	22	411	321.00	114.76	361.49	\$ 71,723
14	YTD	19219	4618.12	24	408.92	323.08	1491.36	4697.80	\$ 932,102

Figure 59: Example of calculations of arrival efficiency performance benchmarking

Appendix Q demonstrates the importance of Airport Operator monitoring of CCO / CDO. For airports that do monitor CCO / CDO performance, giving feedback to the Aircraft Operators can help them formulate their CCO / CDO policies should they have no SOPs on CDO, and help develop specific CDO guidance material for those airports.





## APPENDIX M: PHRASEOLOGY

### KEY MESSAGE

**While acknowledging the issues in Europe that have resulted in a current inconsistency in the application of ICAO Amendment 7A phraseology on SID / STAR, ICAO does not plan to review this again. Therefore, the European CCO / CDO Task Force urges States and Regulators to solve any outstanding issues related to the use of this phraseology, transpose into SERA and enable the Europe-wide implementation of Amendment 7A.**

**The Task Force advocates the use of training material for States on Amendment 7A phraseology. Such material may be found on the ICAO public website at**

**[https://www.icao.int/airnavigation/sidstar/Pages/SID\\_STAR-Toolkit-.aspx](https://www.icao.int/airnavigation/sidstar/Pages/SID_STAR-Toolkit-.aspx).**

Historically there has been huge diversity in SID / STAR phraseology, particularly with ATC restrictions, resulting in different implementations in the US and in continental European States. Consequently, about ten years ago, the ICAO ATM Operations Panel (ATMOPS Panel) was requested to come up with a common approach.

In 2016, Amendment 7A to ICAO Doc. 4444 (PANS-ATM) was released by the ATMOPS Panel. The objective of this Amendment was of ensuring that ATC and Flight Crews had a common understanding of specific phraseology instructions, and to remove the huge diversity in previous SID / STAR phraseology.

EASA intended to include the updates to SERA (Standardised European Rules of the Air) but received objections from States and so temporarily stopped the transposition of the SID / STAR phraseology into SERA.

Amendment 7A phraseology is currently not being followed consistently by European States, partly because the legacy ACARS system is not fully compliant with the ICAO standard and partly because some States have stated that they cannot implement Amendment 7A until it is included in SERA, resulting in a 'chicken and egg' situation. A number of other States are not affected by Amendment 7A as they have no published level and speed restrictions on their existing SIDs / STARs.

This has led to some misunderstandings for both ATC and Flight Crew related as to which precise phraseology should be used; this was demonstrated in the HTO Project (see Appendix Q) in Germany where it led to workload issues for ATC.

Misunderstandings were identified in the meaning of the clearance "descend via STAR FLXX" whilst the clearance "cleared EMPAX3W STAR" resulted in some Pilots thinking that this clearance included a descent clearance, which had obvious safety implications.

It should be noted that to obtain maximum benefit from 7A phraseology, SIDs / STARs should be designed in a manner to extract the most from the ICAO Provisions (Standards and Recommended Practices (SARPs), Procedures for Air Navigation Services (PANS), Regional Supplementary procedures (SUPPs) and Guidance Material GM). At the global level, it should also be noted that all the success stories relating to Amendment 7A adoption have all included airspace / procedure design as an integral part of the implementation process.

However, ICAO will not be reviewing Amendment 7A SID / STAR phraseology again and is instead supporting its implementation. It is expected that Amendment 7A SID / STAR phraseology will eventually make its way into SERA and should be an enabler for an improvement in operational efficiency. The objective should be to see all outstanding issues solved.

The European CCO / CDO Task Force promotes the use of training material for European States on Amendment 7A phraseology. Such material may be found on the ICAO public website at <https://www.icao.int/airnavigation/sidstar/Pages/Training-and-Education.aspx>.

The Task Force also expects IATA and CANSO to play a role in advocating Amendment 7A phraseology.

The European CCO / CDO Action Plan promotes the use of ICAO Amendment 7A phraseology as detailed below:

### 1) Basic rules

- A clearance for a STAR with level and / or speed constraints consists of a lateral and a vertical part.
- Lateral part: "XY123, cleared (Designator)"
- Vertical part: "XY123, descend via STAR FL (figures)"
- Adherence to waypoint constraints is mandatory after a "descend via STAR FL (figures) clearance."
- Do not descend below the flight level cleared by ATC
- The term "via" shall not be used for lateral clearances

### 2) CORE phraseology vertical clearances:

- "Callsign....descend via STAR FLxxx" e.g. DLH123 descend via STAR FL100
- "Callsign....climb via SID FLXXX" e.g. CFG456 climb via SID FL240

### 3) CORE Phraseology for removal of level and/or speed restrictions:

- "Callsign....descend unrestricted FLxxx" e.g. DLH123 descend unrestricted FL100 (ALL restrictions / constraints are cancelled)
- "Callsign....descend via STAR FLxxx, cancel level (or speed) restriction"
  - e.g. DLH123 descend via STAR, cancel level restrictions
  - e.g. CFG456 descend via STAR, cancel speed restrictions

### 4) Special Situations – Part 1: Proceed DCT to point on a STAR/SID with remaining constraints:

- "Callsign....proceed DCT XXX....descend via STAR FLXXX" e.g. Condor456 proceed DCT KOVAN descend via STAR FL100

The speed and level restrictions associated with the bypassed waypoints are cancelled. All remaining published speed and level restriction shall remain applicable.

### 5) Special Situations – Part 2: Vector an aircraft off the STAR and then back to a point of the STAR with remaining constraints:

- "Callsign...proceed DCT....rejoin STAR (designator)...descend via STAR FLXXX"
  - e.g. DLH123 proceed direct FRANC, rejoin DELTA1B Arrival route, descend via STAR A3000ft.

For more information, see <https://www.icao.int/airnavigation/sidstar/Pages/provision.aspx>





## APPENDIX N: COLLABORATION

### **KEY MESSAGE**

**The European CCO / CDO Task Force recognises that collaboration is an essential element in supporting enhanced CDO at two levels:**

- 1) **By using a collaborative forum e.g. a CEM Working Arrangement, to discuss and focus on proposed ATM changes (for example, CCO / CDO implementation) with all operational stakeholders and to identify potential environmental benefits, impacts and interdependencies between different KPAs; and,**
- 2) **Focused ATCO / Flight Crew collaboration is essential for airspace or procedure changes to ensure input and buy-in on both sides ATM changes may be more successfully developed and implemented with such collaboration from the beginning of the project.**

Collaboration and understanding interdependencies are two elements that considerably benefit the operational change process. This can be undertaken at two distinct levels; on a generic higher level, it is good practise to involve operational stakeholders in roundtable discussions on the environmental impact, constraints or benefits from any proposed operational change. One example of this is the Working Arrangement (WA) recommended in EUROCONTROL's Specification on Collaborative Environmental Management (or CEM).

The CEM WA articulated in EUROCONTROL's CEM Specification<sup>26</sup> formalises collaboration amongst the core operational stakeholders at and around airports. The objective is to minimise the environmental impact of their combined operations, by setting out generic, high level requirements and recommended practices necessary for either establishing CEM working arrangements or for flexibly adapting existing ones in a pragmatic protocol to suit local needs and capabilities.

More strategically, CEM working arrangements can also address longer-term operational and planning issues. Examples include the introduction of new airspace design, and the implementation of different approach or departure procedures (such as CCO / CDO, de-icing procedures, planning scenarios for new airport infrastructure and adaptation actions to reduce the impacts of climate change).

CEM benefits and supports core operational stakeholders' common awareness and understanding of the interdependencies and constraints facing each other's businesses. This in turn can facilitate the development of shared environmental solutions, on which they can then collaborate in joint planning and implementation.

CEM can therefore be used to facilitate enhanced relationships; for example, ANSPs assisting airports with capacity issues, and airports and ANSPs assisting airlines with fuel savings, so contributing to high performance airport operations.

The European CCO / CDO Task Force not only supports the creation of such collaborative forums but also actively recommends that each forum contains a specific and fixed item related to CCO / CDO on the agenda.

In addition, whilst the CEM WA is usually focused on the local (airport) level, in the case of optimised CCO / CDO, discussions should not be limited to low level CCO / CDO (CCO / CDO noise). It should be noted that stakeholders that are involved in optimising CCO / CDO might not be in the immediate vicinity of the airport in question. For example, for arrivals to Brussels (EBBR), descent may start in Brest airspace (France) with inefficient intermediate level segments in Reims and Maastricht airspace, with the Belgian ANSP only taking responsibility for the profile from FL245.

26- <https://www.eurocontrol.int/initiative/collaborative-environmental-management>

In this case, it would be useful to propose additional / temporary memberships of the group for stakeholders who may be responsible for operations outside of the immediate vicinity of the airport and therefore, responsible for the trajectory (and thus CDO Fuel) from ToD, in order to discuss environmental performance improvements.

In such collaborative forums it is important that all stakeholders are engaged e.g. from the Aircraft Operator side, it is not just Commercial Aviation that should be represented. Depending upon the individual airport, it may also be pertinent to engage with Business Aviation stakeholders in particular as their aircraft may have differing flight profiles, particularly on departure, to other commercial aircraft types.

On a more focused level, when undertaking an operational change such as a route or procedure change, **it is essential for ATC to work together with the airspace users to ensure that the outcome is an optimal result for all stakeholders.**

Even when there is no specific operational change to discuss, it is recommended that operational personnel jointly initiate, and form an active part of, a systematic exchange of views between Airspace Users and ANSPs on procedures for optimising CCO / CDO. This should be encouraged both at the individual Pilot / ATCO level and at the institutional level, particularly at airline home bases.

If an airport already has a CEM Working Arrangement, a specific item may be added to the agenda to cover this point. It is essential that, due to the impact of noise on surrounding communities, the airport operator should also be consulted about changes to arrival and departure procedures. This three-way collaboration among operational stakeholders is critical to success.

One example of an outcome of a CEM working arrangement could include the good practice material as found in Figure 60 where the ANSP and national airline of a European State worked together to develop mutually agreed CDO guidance material for ATCOs and Flight Crews on CDO that was aligned at both the technical and operational level.

## A Pilot's guide to Continuous Descent Operations

Continuous Descent Operations (CDO) result in reductions in noise and fuel consumption. Any measures to reduce fuel use, atmospheric emissions and aircraft noise in the vicinity of an aerodrome remain a high priority for all ATM stakeholders. CDO are a triple win for aircraft operators, the airport and local residents.

## A Controller's guide to Continuous Descent Operations

The aim of a Continuous Descent Operations (CDO) is to provide pilots with the ATC assistance necessary for them to achieve a continuous descent during intermediate and final approach, at speeds which require minimum use of flaps etc. This has significant benefits in terms of noise produced beneath the approach area, and in reduction of fuel used.

Figure 60: An example from one ANSP that has produced collaborative guidance material for both ANSP and airline that is aligned at the ATCO / Flight Crew level for mutual understanding

For a case study on the high level collaboration between Flight Crews and ATCOs on identifying the issues confronting flight efficiency in an Area Control Centre, see Appendix Q.

For a case study on the focused ATCO / Flight Crew collaboration required for a successful CDO implementation project, also see Appendix Q.





# APPENDIX O: FUTURE DEVELOPMENTS

## KEY MESSAGE

**European stakeholders and the SESAR Joint Undertaking are working on the development, definition and validation of new and advanced concepts. Several of these new concepts or deliverables may have an influence on CDO performance, due to the use of new technologies, system support tools and aircraft capabilities.**

**In addition, ongoing and planned studies will develop alternative and complementary metrics using machine learning and the availability of enhanced data sources.**

**The objective of this appendix is to give an overview of the opportunities identified by the Task Force that may lead to further optimisation in the future, but require R&D work before they will be at the requisite technology readiness level for pan-European or fleet rollout.**

## O1: Shallower approaches

It is acknowledged that the average idle descent profile can vary depending on aircraft type, weight, speed profile and atmospheric conditions (wind and temperature). The nominal aircraft descent profile is roughly a 3° glidepath although it varies on a flight-by-flight basis (due to altitude, aircraft weight, aircraft type, wind, weather etc.).

Modern aircraft types with optimised aerodynamic performance may have better lift-over-drag ratio and therefore, a shallower descent angle, while some business aviation aircraft may be optimised for steeper descent profiles. Studies are ongoing to assess the best angles for fuel savings in the descent, and mitigation of noise from arriving aircraft at lower levels.

On newer, more aerodynamically efficient low-drag aircraft (i.e. A350 and B788), it may not be possible to deliver optimal low noise arrivals within current airspace structures with varying base levels as these aircraft types may require shallower descent segments in the initial approach in order to reduce speed on approach and remain in a LP/LD configuration. As an example, passing 6,000ft these aircraft could be approximately 24 track miles to touchdown, rather than the 'normal' situation of 6,000ft at around 20nm to touchdown.

In some instances, descending aircraft are compliant with the current UK CDO definition but operate in a higher drag configuration, such as a shallower descent angle, with additional flaps deployed (as newer aircraft types may require flap at speeds others do not) and higher engine thrust. Overall, this would be noisier than a CDO LP/LD procedure.

LP/LD is the collective term used for describing the lowest noise configuration for a given speed and / or altitude during the approach. Selecting more flap than required for a given speed will typically lead to more airframe noise, higher engine power due to greater drag, and thus increased noise.

A previous review of CDO noise performance undertaken by NATS in 1999 considered only flap angle during the final approach phase and concluded that LP/LD offered no more than 1 dB noise reduction. In contrast, deployment of the landing gear significantly increases airframe noise and aircraft drag, and maintaining the flight path requires increases in engine thrust. The combined effect may be to increase noise by as much as 5 dB (see section 2.2 for more information).

NATS have found that the high compliance percentage associated with the current CDO definition in the UK means that airlines and ATC are not sufficiently incentivised to improve current operations to further reduce aviation noise. An alternative definition is required to incentivise airlines and ATC to make additional reductions in aviation noise, while also adapting it to allow for the optimum low noise arrivals on new aircraft types. Concurrent CDO and LP/LD operations will deliver quantifiable noise benefits, while simultaneously reducing emissions and fuel burn.

Low noise approaches are being studied in the UK by NATS and the UK CAA. The hypothesis in the study is that a combination of new fleet mixes and aircraft performance capabilities can enable shallower angle approaches. This may result in less noise than traditional CDOs (in particular, when the aircraft is changing configuration) and may be a preferred way of flying a low level approach at airports where noise is a particular issue.

An outcome could see aircraft flying lower over the same point on the ground than before, but more quietly. With such an approach, there is the possibility that the vertical descent rate, under some circumstances, could fall below the 300ft/min threshold for level flight segment identification and could therefore be classed as a level (inefficient) segment under the current CDO definition. The study in the UK was based on four aircraft types (A388, B788, A320 and DH8D) and the final conclusions of the study should be available in 2020.

The study's objectives were to investigate and develop a refined assessment methodology for the operation and measurement of low-noise arrivals that accommodate LP/LD operations. The focus was on optimising approaches to deliver an LP/LD configuration in the main areas of concern for approach noise between 7,000ft and 1,800ft above aerodrome level.

A further objective of the study was to develop a new metric that will complement the current CDO definition and provide a new target for reducing arrival noise in the near term on both the current in-service fleet and new aircraft types.

The results indicated that descent profiles in the range of 2.4°-2.7°<sup>27</sup>, dependent on aircraft type, are the optimal angles for the quietest descent in the initial approach phase (below FL70). These descent angles are approximately equivalent to descent rates of 720-810ft/min with an 180kts TAS. The study also confirmed previous work that demonstrated that the noise benefit of a CDO would vary, depending on the altitude and length of level flight associated with a non-CDO, as well as the descent rate and associated thrust settings of the CDO flight.

Previous analysis has shown that a typical non-CDO has approximately 5nm of level flight at altitudes between 3,000 and 6,000 ft. Compared to a perfect CDO, this results in noise increases of up to 2.5 to 5 dB, varying over distances of approximately 10-20nm before touchdown.

## 02: Moving the objective from achieving a continuous vertical profile to an optimised vertical profile

For a large number of flights, there are options available for the FMS to calculate an optimum climb and descent profile, optimised against the business needs of the Airspace User for that flight. However, aircraft are not always able to follow the FMS plan, because ATC needs to ensure that separation between aircraft is always above the separation minima. This may be achieved through strategic constraints published as part of the SID or STAR procedures 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, except where short level-off segments are required for speed adjustment. 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 profile, but also just by adjusting the rate of climb or descent, so that the flight is allowed to climb or descend continuously, but at a non-optimum rate<sup>28</sup>.

27- Based on a 220kts/180kts speed schedule and calculated from 1.06 million flight profiles.

28- A non-optimum rate refers to a rate of climb or descent different from the FMS-calculated rate. A key factor for optimising the descent profile from an aircraft point of view, is to limit any maximum ATC speed constraints in order to let an aircraft decelerate as planned by the FMS.

The ICAO CCO and CDO Manuals (respectively Doc 9931 and 9993) provide guidance for airspace and procedure design based on assumptions of what the most common rates of climb and descent are<sup>29</sup>, but also recommend that constraints be minimised as much as possible. An “at or below” or an “at or above” constraint is preferable to an “at” constraints, because they are less restrictive, and will therefore allow more aircraft to fly their desired or optimal profile.

‘At or below’ constraints may offer an opportunity for optimisation even when they are not consistent with the FMS profiles. The behaviour of a majority of current FMSs is to replace an idle descent path by a geometric path, computed at a constant FPA, after an ‘at and below’ constraint. SESAR research<sup>30</sup> however has confirmed that for aircraft that have been subject to an ‘at or below’ constraint below their FMS-optimum profile in the descent phase, levelling off and calculating a new top-of-descent (which is referred to as re-cruising), is often more efficient than it would be to continue descending.

If the aircraft begins its descent to the next constraint too early, the aircraft would leave its current flight level, where fuel consumption is at its lowest, and would continue its descent at a lower rate (using thrust) to arrive at the next constraint.

Alternatively, the aircraft could maintain the cruise at the current altitude (which is referred to as re-cruise) before descending from the new FMS-calculated optimal descent point to arrive at the next constraint. Even though it may be counter-intuitive, levelling off (re-cruising) and calculating a new top-of-descent - as illustrated in Figure 61 - is typically more fuel-efficient than continuing the descent at a lower rate, which would take the aircraft even further below its optimal profile, so increasing fuel burn.

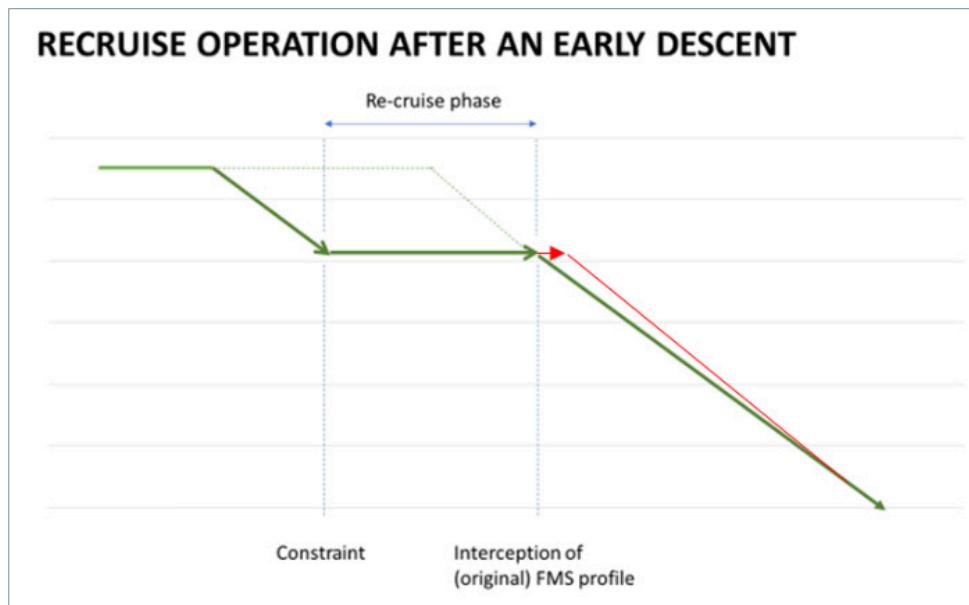


Figure 61: Illustration of a re-cruise operation – demonstrating the new optimised “ToD” obtained by the re-cruising technique

Controllers should be trained to facilitate these fuel saving, intermediate level-offs whenever possible. For aircraft with FMS, a new ToD will typically not be recalculated for the re-cruise; the Flight Crew should use the original descent profile as guidance (by monitoring the vertical deviation indicator when available), and level-off until intercepting the original FMS descent profile.

29- For example, ICAO Doc 9931 proposes that arrival routes be designed to accommodate descent rates of vertical loss over distance in the 220 - 350ft/nm range; (the corresponding rate of descent will depend on the aircraft’s ground speed; for example, for a ground speed of 240kts, 220-350ft/nm would correspond to a rate of descent of 880-1400ft/min, and for a ground speed of 360kts, the corresponding rate of descent to lose 220-350ft / nm would be 1320-2100ft/min, the actual figure depends on the groundspeed of the aircraft)

30- SESAR project PJ.01-03b Validation report, section 5.2.3, available at <https://cordis.europa.eu/project/id/731864/results>

Likewise, during the climb, it will typically be more efficient to climb at a higher rate and level-off until passing an “at-or-below” constraint point than to climb at a lower rate in order to avoid the level-off.

**In summary, a more continuous vertical profile may not always be more efficient**, and there is no simple geometric criterion that allows a straightforward assessment of the efficiency of vertical profiles to be made. The Action Plan (Appendix B) proposes “average time in level flight” as a metric for measuring CCO / CDO performance, a harmonised metric agreed by consensus of the Task Force members, based on their combined experiences and practices of measuring CCO and CDO. Appendix B also explains why the Task Force consider that the proposed indicator is preferable to the binary continuous / non-continuous descent indicator currently in use in RP3, but the Plan does describe its limitations and recommends caution in its interpretation.

SESAR proposes that in the future, a move should be made away from CCO / CDO to OCO / ODO (Optimised Climb Operations / Optimised Descent Operations) to better reinforce the notion that a more continuous profile may not always be the most efficient.

The Task Force urges the R&D community to engage with operational stakeholders in developing sophisticated indicators that use surveillance data to better estimate the efficiency of the vertical profile in the climb and descent phase in terms of fuel and noise impact.

An interesting development activity in this area was presented to the Task Force by ENAC and DSNA, who have used **machine learning** to develop a methodology to estimate fuel consumption and flap settings on approaches.

The development of the model required the use of QAR data, but once the model had been built the fuel consumption and noise impact (based on a combination of an estimation of the engine and flap settings) could be estimated with a high degree of accuracy using only radar data.

The model was developed based on A320 data but was validated against both A320 and B737 QAR data. Mean errors between predicted and overall fuel burn were less than 10kg, with less than 2nm differences between the actual and predicted flap extension points. From these predictions, two indicators were calculated to monitor how efficient the descent was in terms of fuel and noise impact.

The presentation included, as an illustration, examples taken from real flights with descents that included a level-off and yet had a good performance in terms of fuel consumption, and whose efficiency was well captured by the indicators. It also included descent profiles with no level-off (i.e. continuous descent profiles) but were still inefficient in terms of fuel impacts, for which the indicators captured the inefficiency that would be hidden by a time-in-level-flight indicator. These cases highlight a potential limitation of the time-in-level-flight indicator that is proposed in Appendix B as a refinement of the current binary indicators (continuous descent YES / NO).

The Task Force notes that the change of focus from facilitating a continuous descent to facilitating an optimised descent within the existing constraints entails a significant change of mind-set, which will require significant dissemination effort. Extending the scope of the ICAO guidance material to address Optimised Climb Operations and Optimised Descent Operations, instead of the current Continuous Climb Operations and Continuous Descent Operations, will also be required.

## 03: Permanent Resume Trajectory

In current operations, Flight Crews have limited support from the avionics to manage the descent profile when the optimum FMS-calculated profile cannot be facilitated by ATC. As a result, when ATC imposes constraints, the flight must often be flown in selected or manual mode. This results in Flight Crews often having to rely on rules of thumb for deciding which rate of descent to fly when they are being vectored for arrival sequencing or given shortcuts in a trombone or point-merge structure. Often, these rules of thumb need to be combined with assumptions based on their previous experience flying into the same airport regarding what to expect (which speeds, which vertical constraints etc.).

In the SESAR programme, the Permanent Resume Trajectory (PRT) FMS function is being developed to support the Flight Crew<sup>31</sup> in these situations. In the first phase, the concept will be purely airborne and will provide continuous support for the management of the vertical profile in all situations, including while flying on headings. It will also include the possibility for the Flight Crews to enter the planning information as it becomes available to them while being vectored through the "capture at" and "keep track until" sequences (see Figure 62 and Figure 63). In the second phase, the PRT function may be combined with air / ground synchronisation concepts, by allowing the planned resume point to be shared with the cockpit, for instance, so that it can be used for descent planning purposes.

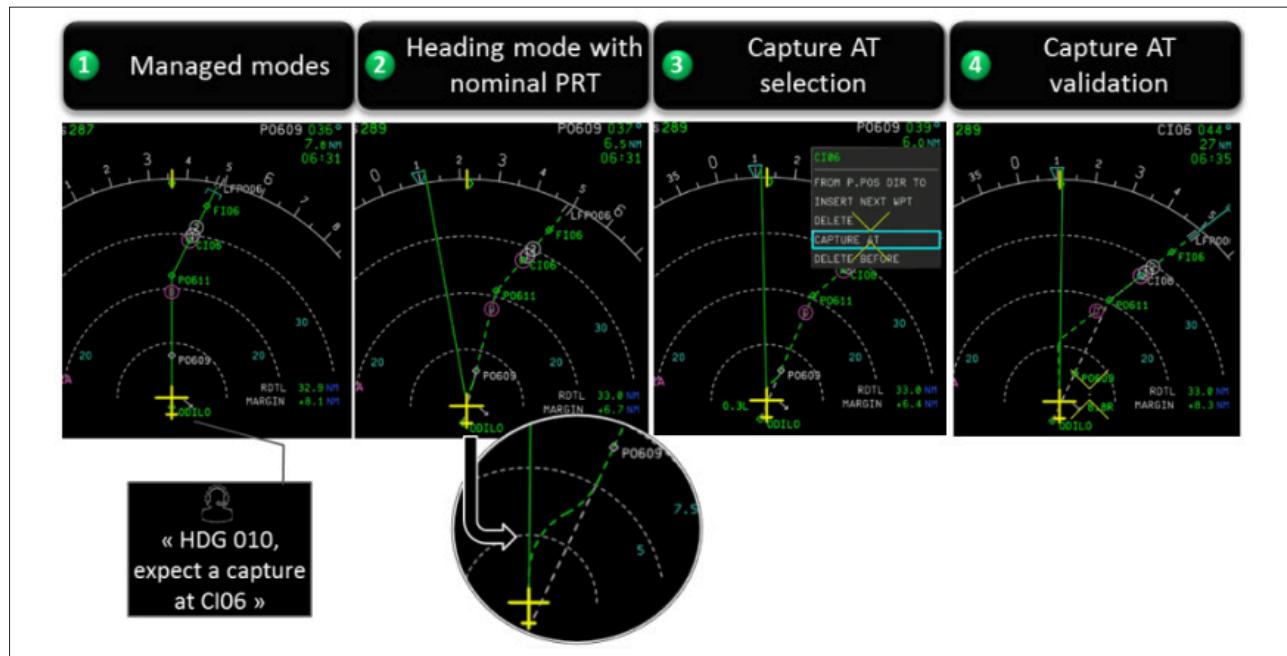


Figure 62: "Capture at" manual adjustment sequence. Source SESAR PJ.01-03b, D.3.4.030 - THALES FMS display visual and layout reproduced by courtesy of THALES AVS and AIRBUS

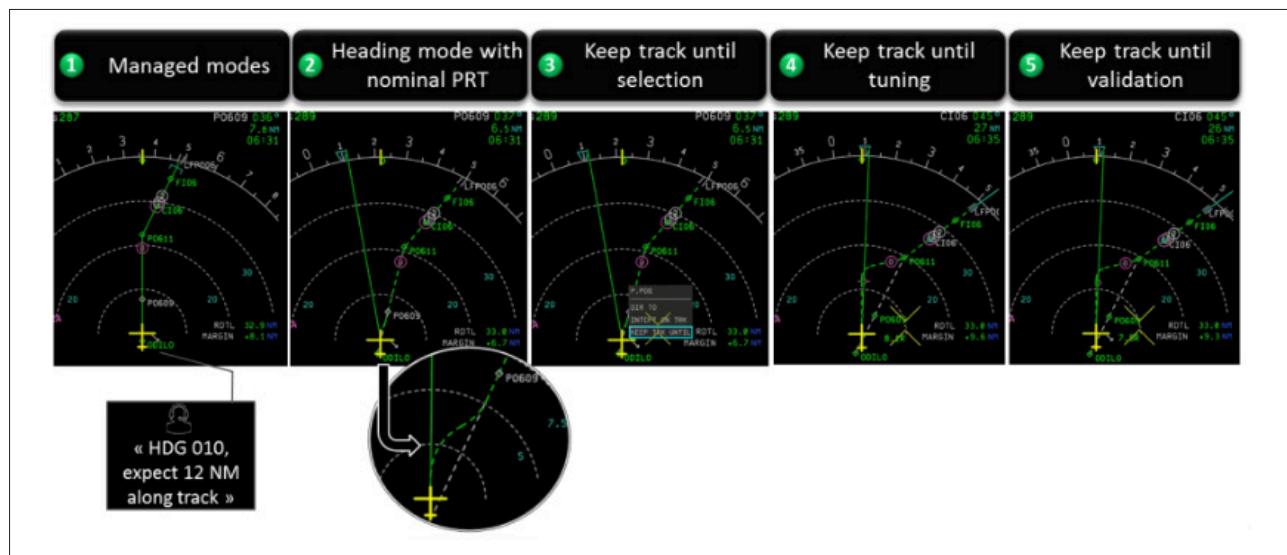


Figure 63. "Keep track until" manual adjustment sequence. Source SESAR PJ.01-03b, D.3.4.030 - THALES FMS display visual and layout reproduced by courtesy of THALES AVS and AIRBUS

31- SESAR solution PJ.01-03b "Dynamic E-TMA for advanced continuous climb and descent operations" (<https://www.sesarju.eu/sesar-solutions/dynamic-extended-tma-e-tma-advanced-continuous-climb-and-descent-operations>) and SESAR 2020 solution PJ.01-08B "Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure operations"

## O4: Floating Track to fix concept

When Controllers vector aircraft for arrival, the uncertainty over the DTG for the Pilot, makes it difficult to plan an efficient descent. The floating track to fix concept is based on the use of a floating fix that can be positioned by ATC to achieve the desired path extension in a more predictable manner than current vectoring techniques. ATC tools would be useful to support Controllers in managing the position of the floating fix and could be synchronised with an AMAN schedule. This concept could have synergies with the advanced PRT concept, where the Controller will share the planned point where the aircraft will be cleared to resume its own navigation with the cockpit. The floating track-to-fix concept has been described by EUROCONTROL<sup>32</sup>, but is not currently being developed by any research project.

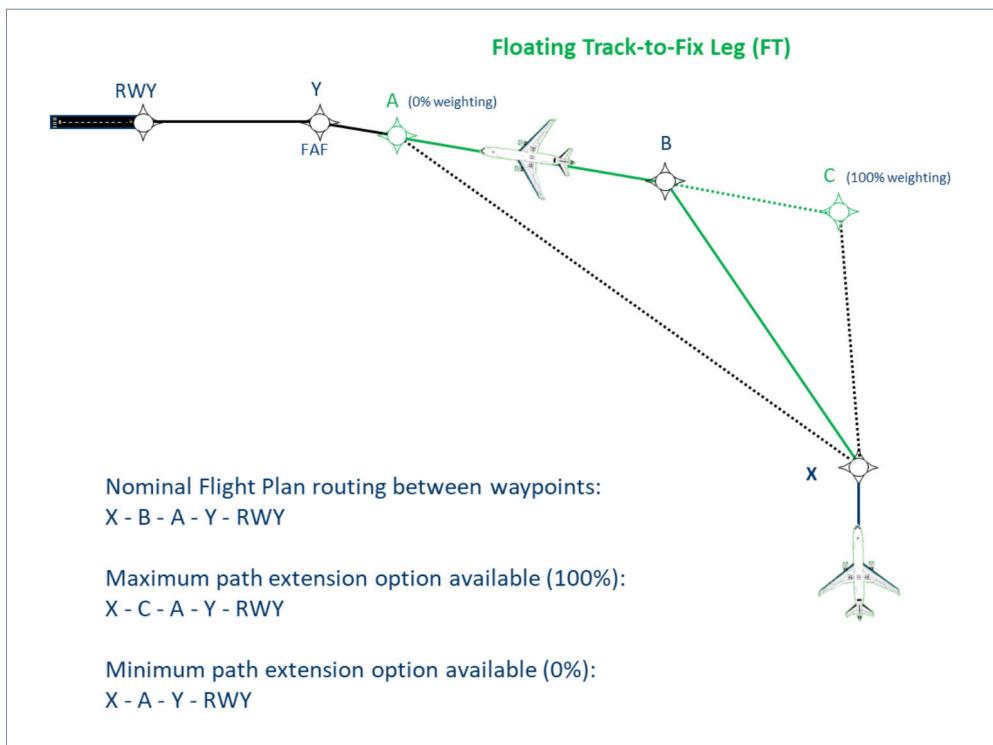


Figure 64: Floating Track to Fix (FT)

## O5: Dynamic attribution of arrival routes

In the arrival phase, arriving aircraft converge towards the airport, and aircraft naturally need to get closer to each other, making maintaining lateral separation between aircraft (with minima normally being 5nm in en-route airspace and 3nm in the terminal area) more challenging.

ATC frequently needs to resort to vertical constraints. Where airspace is available, the “dynamic attribution of arrival routes” concept may mitigate the need for vertical constraints. The concept is based upon assigning laterally separated routes to aircraft, in combination with speed or time constraints, in order to delay the point of convergence until the longitudinal separation has been achieved, so that there is no need for vertical constraints.

Figure 65 shows an example of the Point Merge route design that was used for a SESAR real time simulation in the Paris Orly airport environment.

32- De Smedt (2019). Continuous Descent Operations Future Ideas.

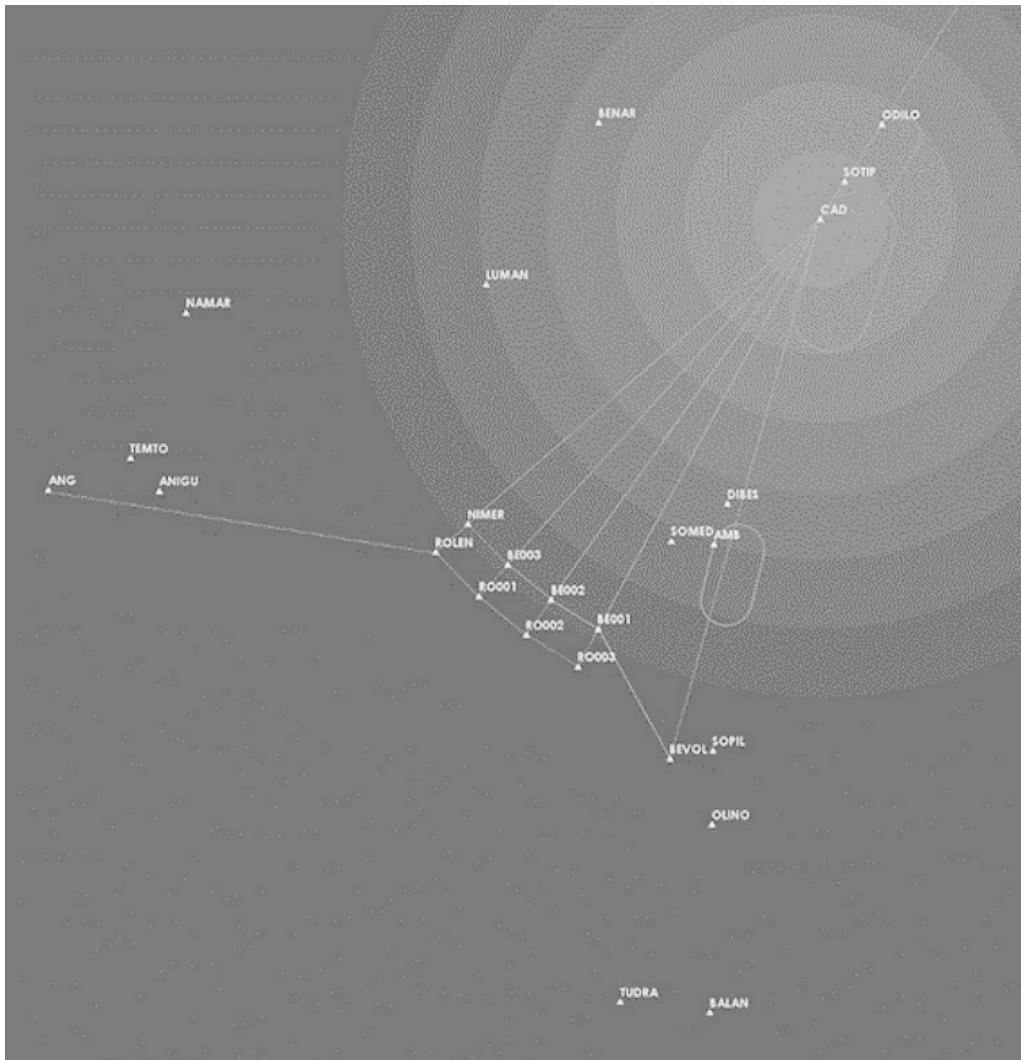


Figure 65: Example of arrival routes for the dynamic arrival route attribution concept.  
Source PJ.01-03b, D.3.4.030

## 06: Enhanced Vertical Clearances

The Extended Projected Profile (EPP) makes it possible for ATC to receive information on the FMS predicted profile. The "Enhanced Vertical Clearances" concept is being researched in SESAR<sup>33</sup> uses EPP information to enhance vertical profiles. The idea is to up-link vertical constraints that must be taken into account by the FMS in its calculation of the predicted profile of the aircraft. This will ensure that vertical separation is maintained, and so reduce the uncertainty in the vertical domain.

These constraints are only imposed where necessary, and allow Controllers to maintain vertical separation with a minimum of deviation<sup>34</sup> required by aircraft away from their FMS profiles, in situations where today they would either have to level-off or adopt a rate of climb or descent that is not necessarily consistent with what the FMS considers to be the optimal profile. In the cockpit, the constraints are received as a CPDLC message. In the current systems, the message can be auto-loadable, but only if it is uplinked to the whole route. The usability of the auto-loadable messages will be improved in the future.

33- SESAR 2020 solution PJ.10-02b "Advanced Separation Management" (<https://www.sesarju.eu/sesar-solutions/advanced-separation-management>) and SESAR 2020 solution PJ.18-W2-56 "Improved Vertical Clearances through Enhanced Vertical Clearances".

34- It should be noted that when vertical constraints are used for separation, compliance needs to be assured. This links the success of this concept to the related concept described in section 0.9 of this appendix, "Addressing the automatic deletion of FMS constraints issue".

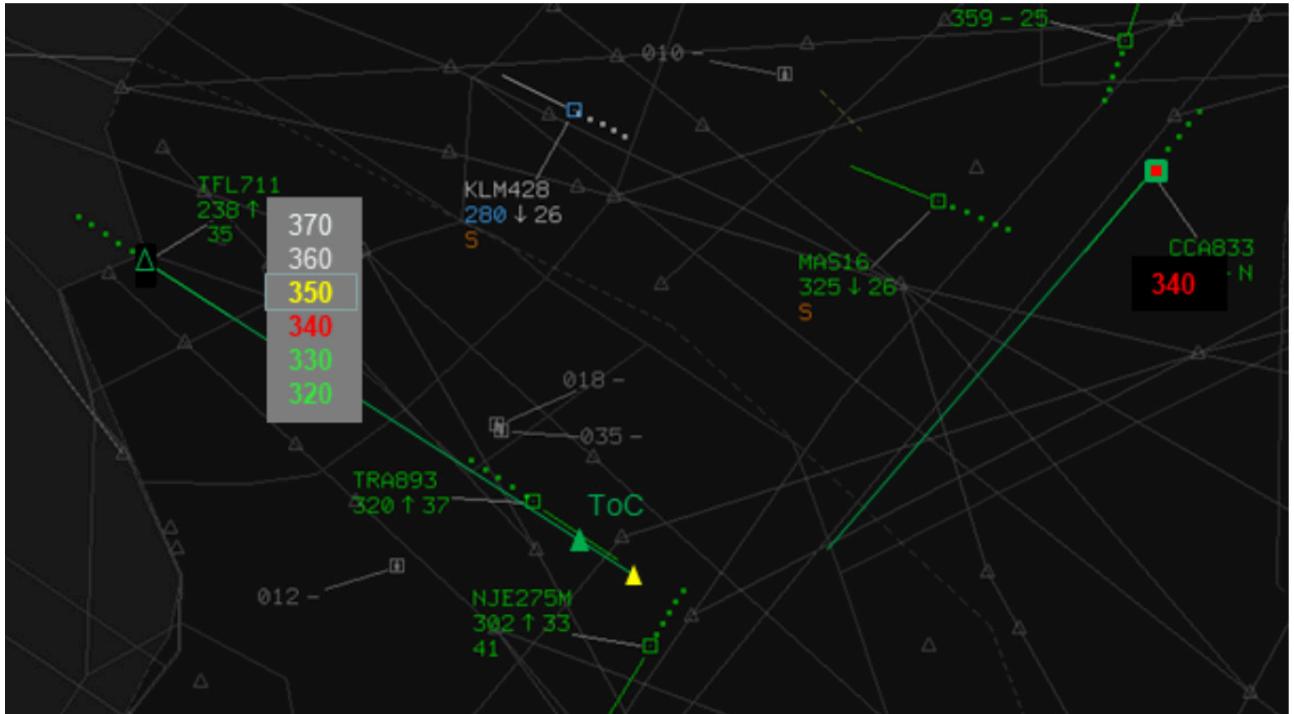


Figure 66. Example of prototype Controller HMI used in SESAR V1 validations of the Enhanced Vertical Clearance concept.

Source: PJ.10-02b, D5.1.030



Figure 67. Example of auto-loadable CPDLC messages with a vertical constraint. Source: PJ.10-02b, D5.1.030

## 07: Extension of CPDLC below FL 285

When information or clearances are uplinked via Controller Pilot Data Link Communications (CPDLC), there is a possibility that they can be auto-loaded to the FMS<sup>35</sup>, which opens up more opportunities for optimisation. In current operations, CPDLC is only available above FL285 so that the Required Communication Performance (RCP) and cockpit Human Machine Interface (HMI) are adapted to the needs of the en-route environment. It is acknowledged that for CPDLC to be extended to lower levels, the technical and operational requirements would need to be adapted to the more dynamic environment of the climb and descent phases of flight. Important human performance issues (such as Pilot head-down time) would also need to be addressed.

For some of the concepts detailed in this Appendix, CPDLC is essential (e.g. the enhanced vertical clearances concept). Even when the concept does not strictly require CPDLC, there may be opportunities for optimisation if it were available (e.g. in the DTG concept, where the information could be sent directly to the FMS).

The SESAR programme has conducted preliminary research into datalink extension<sup>36</sup> and is also developing the technical enablers that will support datalink with lower latency, as per the requirements put forward in the Communications Operating Concept and Requirements for the Future Radio System (COCR) version 2.0<sup>37</sup>. The future datalink service will be provided in a service-oriented multilink environment<sup>38</sup>; the service will be available in all operational environments, and SESAR developments include new terrestrial datalinks through the 5GHz band (AEROMACS<sup>39</sup>) and the L-band (LDACS<sup>40</sup>), as well as datalink via satellite<sup>41</sup>.

## 08: Consideration of the FMS Top of Descent (ToD) by ATC

In busy airspace, ATC often asks aircraft to start their descent before the FMS-calculated ToD. This sometimes responds to a real need for the aircraft to comply with a vertical constraint, but in some cases may simply be due to Controller workload management, i.e. the Controller providing the descent clearance early in order to free resources for other tasks to be performed later. The ToD can be sent to the ground through the EPP. It is expected that the availability of the ToD on the ground will reduce the rate of early descents.

The related “descend-when-ready automatic clearance” concept is based on the automatic uplink of the descend-when-ready clearance so that an aircraft can descend at its own discretion, provided the conflict detection function has not detected any conflicts.

The Controller is, of course, always able to cancel the automatic uplink or to modify the clearance at any time after it has been issued. This more advanced concept addresses, in particular, the early descent requests motivated by the need for Controllers to manage their workload. It requires EPP, and is currently being researched in the SESAR programme<sup>42</sup>.

35- On modern FMS with 4D trajectory functionality only

36- ATC Full datalink Large Scale Demonstration (report available at <https://www.sesarju.eu/node/1506>)

37- EUROCONTROL and FAA (2007). Communications Operating Concept and Requirements for the Future Radio System (COCR) version 2.0. [https://www.eurocontrol.int/sites/default/files/field\\_tabs/content/documents/communications/cocr-future-radio-system-v.2.pdf](https://www.eurocontrol.int/sites/default/files/field_tabs/content/documents/communications/cocr-future-radio-system-v.2.pdf)

38- SESAR 2020 solution PJ.14-02-04 “Future Communications Infrastructure (FCI) network technologies” and SESAR 2020 solution PJ.14-W2-77 “FCI services” <https://www.sesarju.eu/index.php/seesar-solutions/fci-network-technologies>

39- SESAR 1 solution 102 “Aeronautical mobile airport communication system (AeroMACS)” (<https://www.sesarju.eu/index.php/seesar-solutions/aeronautical-mobile-airport-communication-system-aeromacs>), and SESAR 2020 solution PJ.14-02-06 “AeroMACS integrated with ATN, Digital Voice and Multilink” (<https://www.sesarju.eu/index.php/seesar-solutions/aeromacs-integrated-atn-digital-voice-and-multilink>)

40- SESAR 2020 Solution PJ.14-02-01 “Future communication infrastructure (FCI) terrestrial datalink” and SESAR 2020 solution PJ.14-W2-60 “FCI Terrestrial Datalink and A-PNT Enabler (L-DACS)” (<https://www.sesarju.eu/index.php/seesar-solutions/future-communication-infrastructure-fci-terrestrial-datalink>)

41- SESAR 2020 Solution PJ.14-02-02 and SESAR 2020 solution PJ.14-W2-107 “Future Satellite Communications Datalink (FCI Datalink)” (<https://www.sesarju.eu/seesar-solutions/future-satellite-communications-datalink-fci-datalink>)

42- SESAR PJ.18-02a and W2-PJ.18

## O9: Addressing the automatic deletion of FMS constraints issue

The descend- and climb-via SIDs and STARs instructions aim at enabling CCO and CDO through a series of vertical constraints along the trajectory in order to de-conflict traffic flows and ensure clearance from terrain, but in some cases, their implementation has been hindered by the lack of compliance with the constraints<sup>43</sup>.

It is known that some of the instances of non-compliance are associated with the automatic deletion of certain constraints in some FMSs, whose logic was not designed to support the systematic use of constraints that is required by descend-via and climb-via instructions. It is not known if this issue may also affect the ad-hoc constraints uplinked via CPDLC for the “Enhanced Vertical Clearances” concept described above. R&D is needed to develop the avionics and associated Flight Crew procedures to ensure that vertical constraints are not deleted under any circumstances, e.g. by ensuring substitution by a constraint in the abeam point in the situation in which a later waypoint becomes the active waypoint (for example in the case of a direct-to clearance). This will avoid the deletion of constraints that are initially considered superfluous by the FMS because they are in agreement with the FMS calculated profile and are therefore non-constraining, but may become constraints if the clearance changes, etc.

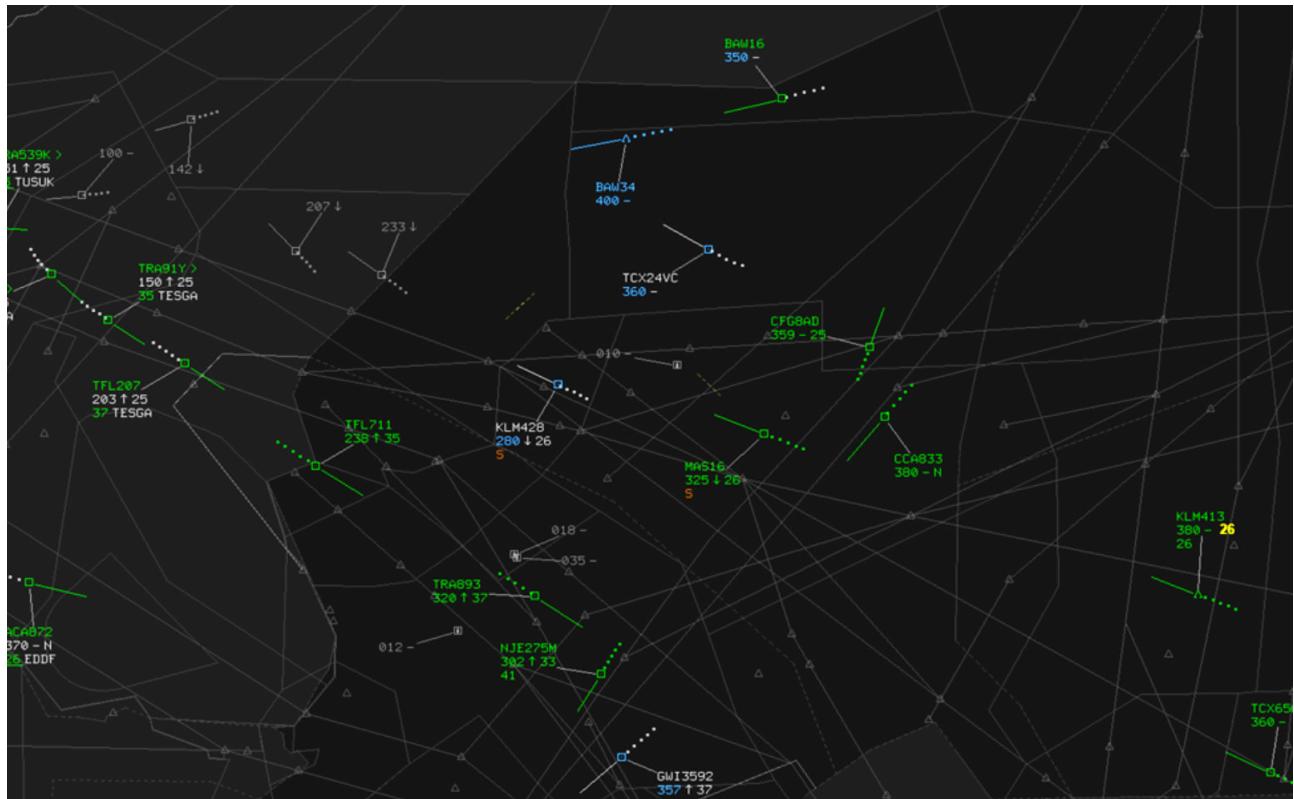


Figure 68: Illustration of the “descend when ready” automatic clearance concept: the Controller HMI shows a yellow hourglass icon to indicate the automatic clearance will be automatically uplinked unless blocked by the (human) Controller.

Source: SESAR W1-PJ.18-02a project

43- See, for example, SESAR Optimised Profile Descent Demonstration report. LSD.01.03-D03, section 6.7.3.1.1.2.5.1. Document available at: <https://www.sesarju.eu/newsroom/brochures-publications/optimised-descent-profiles-odp>

## 010: Improvement of Flight Crew support for management of vertical constraints

It is expected that the number of vertical constraints will continue to increase (see, for example, the enhanced vertical clearances concept described above) and, as a result, the on-board monitoring process of compliance will inevitably become more complex.

R&D is needed to make it easier for Flight Crews to introduce vertical constraints into the FMS and monitor the evolution of the flight, taking vertical constraints into account. These developments will facilitate the flying of the path in “managed mode”, so reducing the time flown in other modes, and thus allowing Pilots to extract the maximum benefits from the FMS’s optimisation possibilities.

## 011: Including limitations to the descent speed in published procedures

The FMS-calculated profile is optimised against the weather and flight-specific performance parameters while taking into account the CI. An Aircraft Operator for a specific aircraft type usually defines the CI; it reflects the cost of time versus the cost of fuel, with CI zero representing the minimum fuel burn for the trip, at the expense of a longer flight time. Higher CI settings result in higher speeds in all phases of flight. Regardless of the CI, the FMS-calculated descent will be at near-idle thrust. During the climb, the higher the CI, the shallower the climb path will be, while during the descent, the higher the CI the steeper the descent path will be. In addition to the CI, the aircraft weight and the forecast weather parameters will also affect the climb and descent profile angle calculated by the FMS.

For ATC, the arrival sequencing and separation task becomes more complex when aircraft are flying at different speeds, and the tendency in busy airspace is to restrict speeds to make them uniform.

Unless speed reduction is needed to absorb delay, Controllers will typically try to minimise the penalisation that speed restrictions cause by instructing aircraft to fly “the most common speed”, which may require some aircraft to fly faster than they would otherwise have done.

Even though the establishment of published speed restrictions always requires a local study, it would be useful to conduct R&D to establish generic rules on where speed restrictions may support an overall reduction in fuel burn. ANSPs could then use the studies to assess the role that speed restrictions may play in their operational environments.

## 012: Development of new FMS algorithms

The European CCO / CDO Action Plan is aimed at providing guidance on how to make it possible for aircraft to fly closer to the FMS profile. However, there may also be room for improvement in the FMS itself. For example, fuel saving opportunities have been identified by using a variable speed setting during the descent, which allows fuel consumption to be reduced further below the current minimum obtained by using a constant speed setting at cost index zero<sup>44</sup>, but at the expense of a longer flight time. R&D is required to advance on these ideas.

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44- Altava, R., Mere, J., Dlahaye, D., & Miquel, T. (2018). Flight Management System Pathfinding Algorithm for Automatic Vertical Trajectory Generation. DASC 2018. London (United Kingdom): 37th AIAA/IEEE Digital Avionics Systems Conference

## 013: SID allocation at the runway holding point based on aircraft performance data

In complex TMAs containing two or more airports, conflicting departures from two different airports are often separated by the incorporation of vertical constraints in the SIDs, with the same constraints being applied regardless of the aircraft type and planned vertical profile.

For example, departures from airport AAAA will always be below departures from airport BBB, or will fly a SID over a certain waypoint that is not available to departures from other airports. The availability of eFPL data makes it possible to better anticipate the climb profile, so that different SIDs can be allocated (e.g. with the same 2D path but a different set of vertical constraints, or with an altogether different SID) depending on the anticipated conflicts, e.g. by giving heavy aircraft shallower climb profiles.

To a certain extent, this could be done strategically as part of the departure clearance, taking into account the rate of heavy versus medium aircraft expected at both airports at the time a flight is expected to take off. However, given the uncertainty on the duration of the taxi-out phase, for maximum benefit it would be necessary to allow the SID to be updated at the runway holding point, which is not possible today.

However, this could also result in a significant increase in Flight Crew workload, which would need to be mitigated. SESAR research<sup>45</sup> has considered this type of operation on a conceptual level, but no validations have yet been planned.

Another option that could be further investigated is the optimisation of lateral departure routes so that they no longer conflict with other departure or arrival routes and so vertical constraints would no longer be required. An example is a departure with an early turn.

## 014: Use the dataset of downlinked EPPs to improve SID and STAR design and ATC procedures

In current operations, SIDs, STARs and ATC procedures are designed according to standard performance parameters, as ICAO's general guidance stipulates. In the best of cases, a performance model for the specific traffic mix that will be affected is used, in order to minimise the impact of constraints for the typical aircraft types that fly in the area. Once initial trajectory sharing is deployed, it will be possible to build and maintain a dataset of the EPPs showing the FMS profiles that Airspace Users flying each route would have liked to fly and compare them to what was actually flown. **This will make it possible to design procedures with fewer penalising constraints.**

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45- SESAR solution PJ.01-03b "Dynamic E-TMA for advanced continuous climb and descent operations"  
<https://www.sesarju.eu/sesar-solutions/dynamic-extended-tma-e-tma-advanced-continuous-climb-and-descent-operations>)  
 and solution PJ.01-02 "Use of arrival and departure management information for traffic optimisation within the TMA"  
<https://www.sesarju.eu/sesar-solutions/use-arrival-and-departure-management-information-traffic-optimisation-within-tma>)

## 015: Airspace or operations? Analysing the factors affecting vertical efficiency in descent

Work has been undertaken to analyse the factors affecting vertical efficiency in the descent phase and, in particular, to quantify the respective contributions of airspace and operations to this efficiency. The aim was to identify, for each airport, the potential sources for vertical inefficiency to which mitigations can be applied to deliver CDO performance improvements. The analysis relies on measuring the vertical deviations from two types of reference profiles, a CDO profile common to all airports or 'best profiles' of each airport, in relation to the horizontal deviation<sup>46</sup>.

How does it work? Figure 69A below shows the vertical profiles of a downwind flow in the time period 0-25 minutes before final at a given airport, which approximately corresponds to a 50nm area around the airport. A systematic level-off at FL110 may be noticed, corresponding to path stretching (vectoring prior ILS intercept).

Figure B displays a typical CDO profile (3° slope, orange) from the entry altitude in the 50nm area, extended to the maximum flight time observed. Figure C introduces the notion of best profile (90th percentile).

Two inefficiency factors can then be isolated as is shown in Figure D. More precisely, overall inefficiency can be defined as the vertical deviation from the CDO profile, the operation inefficiency as the vertical deviation from the best profile, and the airspace inefficiency as the difference between both.

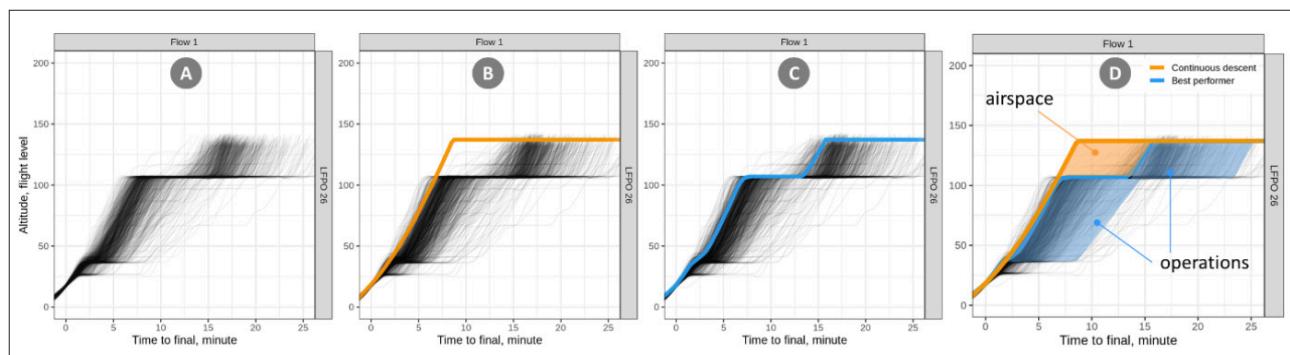


Figure 69: Vertical profiles showing A, a systematic level-off, B, a typical CDO profile, C, the 90th percentile, and D, the inefficiency factors

The top 30 European airports were analysed focusing on the 50nm area, in daytime operations, and using one year of data from 2019 - to measure the extent of airspace versus operations vertical inefficiencies.

Figure 70 (left) shows the airspace versus operations inefficiencies (structural versus tactical deviation). It reveals a variety of situations: the "big" terminal areas (London, Frankfurt, Amsterdam, Paris, Madrid, Munich) show logically the highest airspace inefficiencies, and the airports with high levels of congestion (additional time) show the highest operational inefficiencies (EGLL, EGKK, EIDW, LPPT). These findings may indicate possibilities for improvements by addressing operations. Figure 70 (right) focuses on the operations and shows the vertical versus horizontal inefficiency (tactical deviation vs additional time). It reveals that the vertical deviation tends to increase with the additional time, however there are exceptions for airports with a lower vertical deviation and a higher additional time than others (e.g. LIMC or LIRF vs LEBL or LSZH). This suggests that the horizontal inefficiency is a key factor that can be attenuated.

46- P. Pasutto, E. Hoffman and K. Zeghal, "Vertical efficiency in descent compared to best local practices", 13th USA/Europe Air Traffic Management R&D Seminar, Vienna, Austria, June 2019.

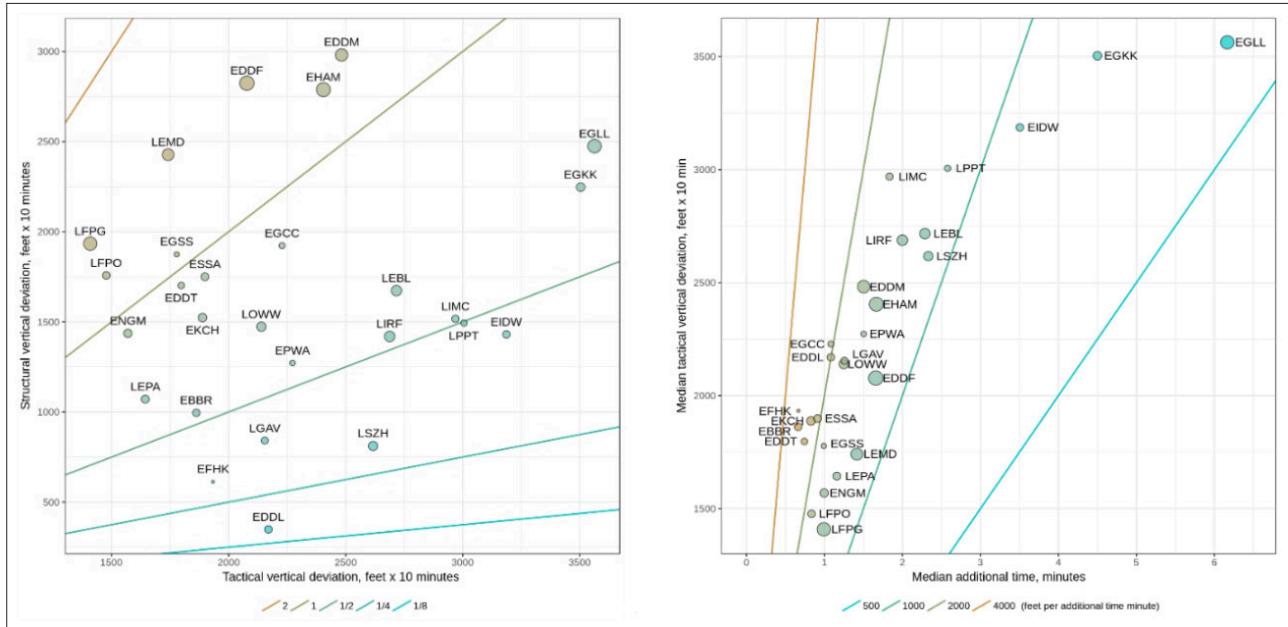


Figure 70: The structural versus tactical deviation of vertical inefficiencies (left) and the tactical deviation versus additional time (right)

To better understand the source of the operational inefficiency, let us consider two major airports with diverse situations (EGLL and EHAM). Figure 71 shows the vertical deviation above and below FL70 as a function of the additional time (each dot representing a flight; median and 90th containment displayed). This view reveals:

1. The effect of the additional time on the vertical deviation (median); and,
2. The dispersion of the vertical deviation for the same additional time (90th containment).

It also highlights differences due to metering and sequencing techniques: below FL70 EHAM shows a significant variability increasing with the additional time; EGLL shows a constant and limited deviation due to CDO.

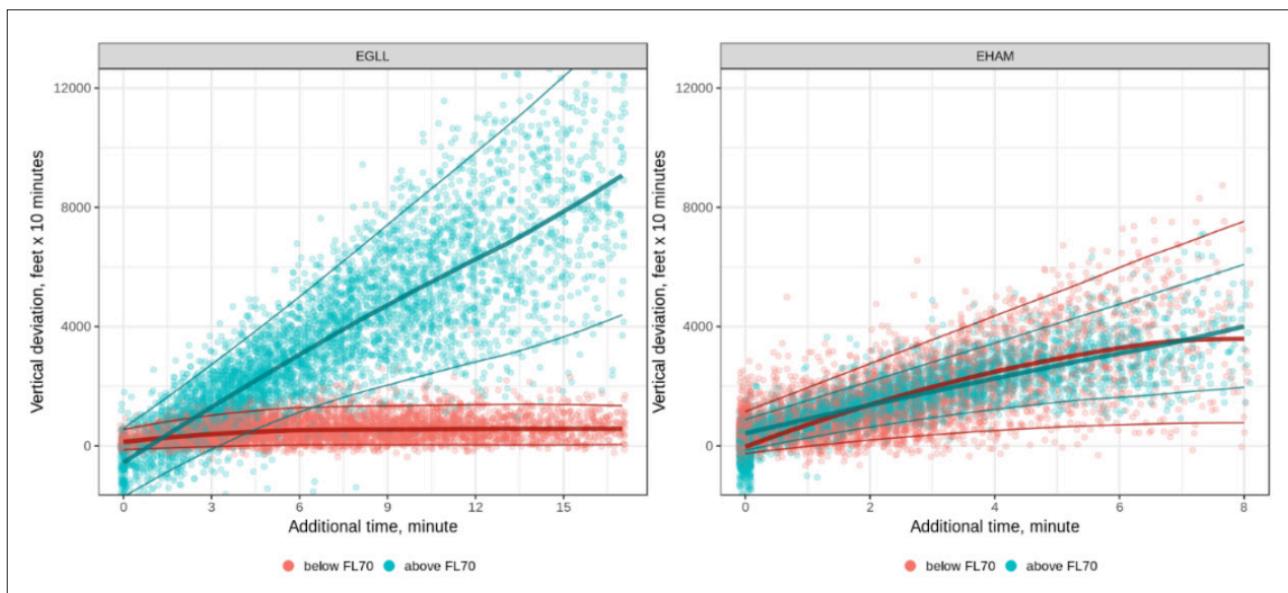


Figure 71: the vertical deviation above and below FL70 as a function of the additional time at EGLL and EHAM

In conclusion, this work suggests that in order to improve vertical efficiency and CDO performance three aspects may be considered, depending on each airport:

- Reducing the spread of (tactical) vertical deviation for the same horizontal deviation by reinforcing adherence to best local practices and systematisation of the working methods;
- Reducing the impact of horizontal deviation on (tactical) vertical deviation, by using a sequencing technique to facilitate CDO; and,
- Reducing the (overall) vertical deviation by re-considering airspace constraints whenever possible.

## 016: Introduction of flight efficiency considerations in conflict resolution tools

There is also potential for improvement in the area of conflict resolution tools, which may introduce flight efficiency considerations, and recommend the most efficient solution to Controllers. For example, when level-off clearances are needed for ensuring separation between climbing and descending aircraft, a conflict resolution tool may recommend the most appropriate level for reducing the negative impact on fuel or noise, while including equity considerations (to avoid having some Airspace Users – for example those with lighter aircraft - systematically receiving less favourable clearances).

These concepts can be advanced without air / ground synchronisation concepts, e.g. based on fuel burn models, but data downlinked from the aircraft would open more possibilities, by including aircraft specific data.

## 017: Extension of the ground to air sharing of DTG information

The ground-to-air sharing of the DTG information is already used at some airports and helps Flight Crews plan their descent in the last portion of the flight. Specific tools to assist Controllers in calculating the DTG may make it possible to extend this concept where it is challenging for Controllers to make the prediction. For airports where the information is already given today, a support tool may make it possible to give this information earlier on in the process than is usually done at present.

## 018: Use of Quick Access Recorder Data

As explained earlier in this document, there are no straightforward geometric criteria for assessing the efficiency of the vertical profile. Moreover, traditional fuel assessment methodologies have been shown to have some limitations<sup>47</sup>.

The CCO / CDO Task Force has identified the potential for improving the assessment by using data from the on-board QAR. QAR data can provide invaluable insight into fuel burn information and allow statistical analysis of the fuel burn and the degree of adherence to published procedures.

This information can be used in multiple ways by the Airspace User, e.g. for Flight Crew procedure development and the design of training programmes for improving Flight Crew fuel management techniques.

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47- SESAR Optimised Descent Profiles Demonstration report. LSD.01.03-D03, section 5.3.3 (Assessment methodology), document available at <https://www.sesarju.eu/newsroom/brochures-publications/optimised-descent-profiles-odp>.

In addition, the data can provide information on the degree to which a published procedure is actually made available to the Airspace User through an ATC clearance. It can provide a reliable way for Airspace Users to assess the impact that changes implemented in airspace design can have on fuel burn. An example below shows a typical StorkJet interface for visualising the potential of using QAR data in CCO/CDO performance measurements.

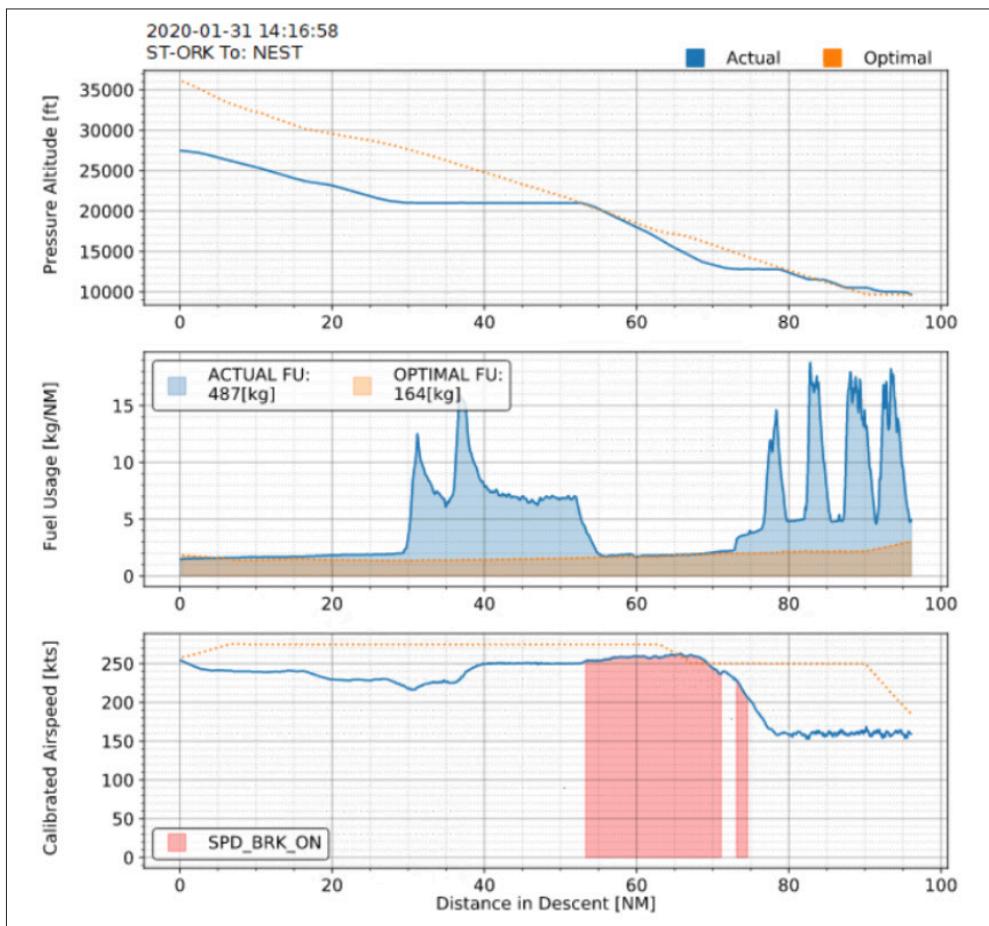


Figure 72: An example of an interface that visualises potential of using QAR data for CCO/CDO performance measurement (source: Storkjet)

At present, another company that analyses QAR data, Jeppesen, is developing a fuel dashboard as part of its data analytics services. The fuel dashboard will allow precise analyses of CCO / CDO performance to be made; it will use fuel burn data from the QAR and the harmonised parameters agreed by the European CCO / CDO Task Force.

It should also be noted that not all FDM data can be shared for performance measurements. There are many airlines, German airlines for instance, which have significant union restrictions on their use of FDM data, given that performance monitoring in such a way may not be consistent with a non-punitive airline culture.

## 019: Increased or reduced glide slope, variable glideslope and displaced runway threshold

In the final segment of the approach, where the mitigation of noise impact is essential, the increased flexibility made possible by RNAV (LPV or LNAV (Lateral Navigation) -VNAV) procedures and Ground-Based Augmentation System (GBAS) procedures with respect to traditional 3° ILS can be useful. With the IGS (Increased Glideslope) concept, aircraft fly a steeper glide slope, in some cases even above 3.5°, as the higher flight paths may reduce the noise impact over neighbouring communities.

When the runway is long enough, displacing the threshold or setting a Second Runway Aiming Point (SRAP), by itself or in combination with an increased glideslope, may also help reduce noise around the airport. On the other hand, research has also found that in some cases shallower approach paths can also reduce the noise impact.

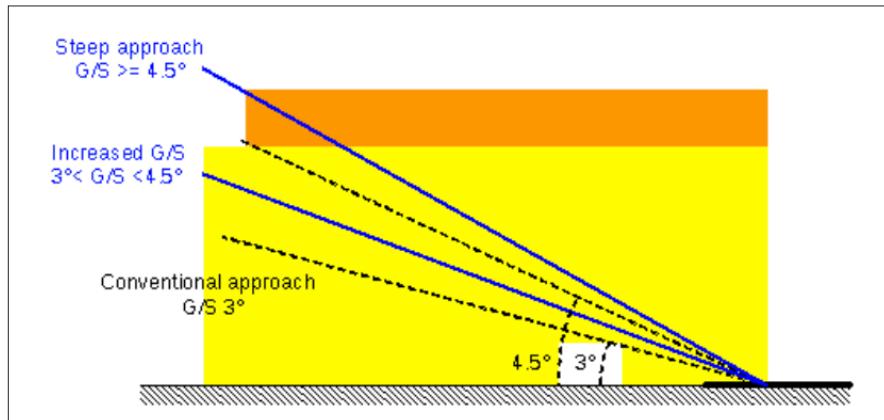


Figure 73. Illustration of the Increased Glide Slope concept. Source: SESAR PJ.02-02-D2.1.046.

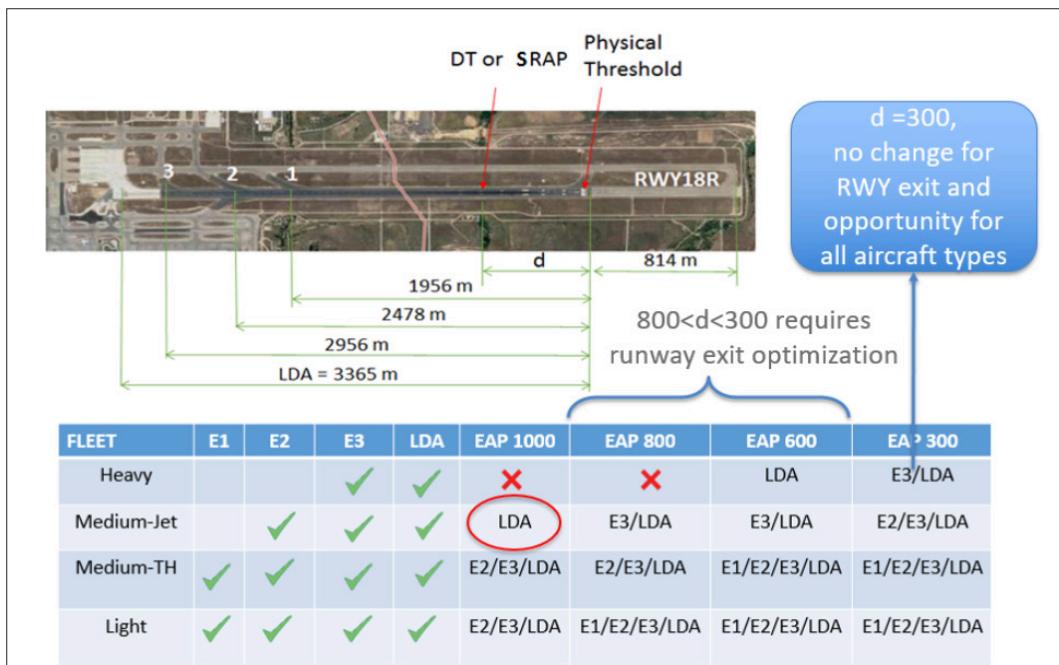


Figure 74. Example of SRAP / Displaced Threshold (DT) concept in LEMD runway 18R used in SESAR validations. Source: PJ.02-02. D2.1.046

## O20: Use of geometric (GPS) altimetry

The use of geometric vertical navigation and optimised barometric-to-geometric vertical transition supports shorter final approach segments. This increases the flexibility of the design of the approach procedures and provides increased opportunities for reducing the noise over populated areas located directly under the extended runway centreline. They also increase flexibility in the design of SIDs and STARs, which may reduce the need for vertical constraints. Advanced curved approaches are currently under research in the SESAR programme<sup>48</sup>.

48- PJ.02-11 and W2-PJ02.



# APPENDIX P: TOOL KIT FOR IMPLEMENTING AND OPTIMISING CCO / CDO

## **KEY MESSAGE**

**The CCO / CDO Tool Kit comprises:**

- 1) The European CCO / CDO Action Plan;
- 2) The CCO / CDO performance dashboard for all airports / airlines in Europe; and,
- 3) The resources detailed on the web pages of the Task Force.

The European CCO / CDO Task Force recommends using the resources of the CCO / CDO Tool Kit for implementing and delivering the performance benefits of CCO and CDO in Europe. The CCO / CDO Tool Kit consists of:

- 1) The European CCO / CDO Action Plan;
- 2) The CCO / CDO performance dashboard for all airports / airlines in Europe; and,
- 3) The resources, guidance and good practice material detailed on the European CCO / CDO Task Force webpages - <https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations> These include:
  - a. The sharing of good practices on CCO / CDO implementation, case studies on implementation and industry developments on CCO / CDO;
  - b. Guidance material for implementation e.g. ICAO documentation on CCO / CDO and impact assessment guidelines for ATM changes;
  - c. The promotion of operational fora where CCO / CDO implementation can be discussed;
  - d. Support in stakeholder consultation;
  - e. Advice on aircraft energy and flight performance management;
  - f. Providing links to where support can be found for the implementation of advanced navigation capabilities (such as PBN) or other operational concepts and innovative solutions (such as Point Merge, Datalink, XMAN, T-bar procedures etc.);
  - g. Support in Airspace and Procedure Design;
  - h. Support in training initiatives on CCO / CDO;
  - i. Information on available support tools; and,
  - j. Resources to support CCO / CDO implementation, performance measurement, Environmental Impact Assessments etc.

These resources include, *inter alia*:

## **EUROCONTROL:**

- 2009 CDA Action Plan - <https://www.eurocontrol.int/publication/european-joint-industry-cda-action-plan>
- European CCO / CDO Task Force web pages - <https://www.eurocontrol.int/concept/continuous-climb-and-descent-operations>
- EUROCONTROL CEM Specification - <https://www.eurocontrol.int/publication/eurocontrol-specification-collaborative-environmental-management-cem>
- ERNIP Part 1 - <https://www.eurocontrol.int/publication/european-route-network-improvement-plan-ernip-part-1>
- IANS Training Zone - <https://trainingzone.eurocontrol.int/ilp/pages/external-dashboard.jsf?faces-redirect=true&dashboardId=6>
- CCO / CDO animation - <https://www.youtube.com/watch?v=mUkMPb5eVJI>
- Guidance for safety assessment of Continuous Descent Operations (CDO) implementation at aerodromes in the ECAC area

**SESAR:**

- SESAR Solutions catalogue - <https://www.sesarju.eu/index.php/newsroom/brochures-publications/sesar-solutions-catalogue>
- SESAR ODP Report - <https://www.sesarju.eu/newsroom/brochures-publications/optimised-descent-profiles-odp>
- AIRE reports - <https://www.sesarju.eu/news-press/documents/aire-2-reports-1034>
- SESAR project PJ.01-03b "Enhanced Arrivals and Departures" Validation report, section 5.2.3, available at <https://cordis.europa.eu/project/id/731864/results>
- SESAR solution PJ.01-03b "Dynamic E-TMA for advanced continuous climb and descent operations" - <https://www.sesarju.eu/sesar-solutions/dynamic-extended-tma-e-tma-advanced-continuous-climb-and-descent-operations>
- SESAR 2020 solution PJ.10-02b "Advanced Separation Management" - <https://www.sesarju.eu/sesar-solutions/advanced-separation-management>
- ATC Full Datalink Large Scale Demonstration - <https://www.sesarju.eu/node/1506>
- EUROCONTROL and FAA (2007). Communications Operating Concept and Requirements for the Future Radio System (COCR) version 2.0.
- SESAR 2020 solution PJ.14-02-04 "Future Communications Infrastructure (FCI) network technologies" and SESAR 2020 solution PJ.14-W2-77 "FCI services" - <https://www.sesarju.eu/index.php/sesar-solutions/fci-network-technologies>
- SESAR 1 solution 102 "Aeronautical mobile airport communication system (AeroMACS)" - <https://www.sesarju.eu/index.php/sesar-solutions/aeronautical-mobile-airport-communication-system-aeromacs>
- SESAR 2020 solution PJ.14-02-06 "AeroMACS integrated with ATN, Digital Voice and Multilink" - <https://www.sesarju.eu/index.php/sesar-solutions/aeromacs-integrated-atn-digital-voice-and-multilink>
- SESAR 2020 solution PJ.14-W2-60 "FCI Terrestrial Datalink and A-PNT Enabler (L-DACS)" (<https://www.sesarju.eu/index.php/sesar-solutions/future-communication-infrastructure-fci-terrestrial-datalink>)
- SESAR 2020 solution PJ.14-02-02 and SESAR 2020 solution PJ.14-W2-107 "Future Satellite Communications Datalink (FCI Datalink)" (<https://www.sesarju.eu/sesar-solutions/future-satellite-communications-datalink-fci-datalink>)
- SESAR solution PJ.01-02 "Use of arrival and departure management information for traffic optimisation within the TMA" (<https://www.sesarju.eu/sesar-solutions/use-arrival-and-departure-management-information-traffic-optimisation-within-tma>)
- SESAR Environmental Assessment Process – SESAR Deliverable D4.0.080 - available on the SESAR Stellar Portal: <https://stellar.sesarju.eu>
- SESAR PJ.18-02a and W2-PJ.18 – Soon to be available at the SESAR JU website: <https://www.sesarju.eu/>
- SESAR 2020 solution PJ.18-W2-56 "Improved Vertical Clearances through Enhanced Vertical Clearances" ([https://www.atmmasterplan.eu/data/sesar\\_solutions/20431936](https://www.atmmasterplan.eu/data/sesar_solutions/20431936))
- SESAR 2020 solution PJ.01-08B "Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure operations" – Soon to be available at the SESAR JU website: <https://www.sesarju.eu/>

**ICAO:**

- ICAO Doc. 4444 – PANS-ATM
- ICAO Doc. 8168 – PANS-OPS
- ICAO Doc. 9931 – ICAO CDO Manual - ICAO Doc 9931\_en.pdf
- ICAO Doc. 9993 – ICAO CCO Manual - ICAO Doc 9993\_en.pdf
- ICAO Annex 6: Operations of Aircraft
- ICAO Doc. 10031 - Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes - ICAO Doc 10031\_en.pdf
- Training material to support Amendment 7A SID / STAR phraseology - [https://www.icao.int/airnavigation/sidstar/Pages/SID\\_STAR-Toolkit-.aspx](https://www.icao.int/airnavigation/sidstar/Pages/SID_STAR-Toolkit-.aspx)
- ICAO 2019 ENV Report - <https://www.icao.int/environmental-protection/pages/envrep2019.aspx>
- ICAO SID / STAR Phraseology examples - <https://www.icao.int/airnavigation/sidstar/Documents/SID-STAR%20Scenarios%20Text.pdf#search=descend%20via%20STAR>
- ICAO Environment Report 2019 - <https://www.icao.int/environmental-protection/Pages/envrep2019.aspx>

### Research Papers relevant to CCO / CDO:

- An Operator focussed metric for measuring predictability and efficiency of descent operations (<https://arc.aiaa.org/doi/abs/10.2514/6.2016-4219> - subscription required)
- Analysis of vertical flight efficiency during climb and descent ([http://ansperformance.eu/references/library/vertical-flight-efficiency-during-climb-and-descent\\_consultation.pdf](http://ansperformance.eu/references/library/vertical-flight-efficiency-during-climb-and-descent_consultation.pdf))
- Assessing vertical flight profiles during climb and descent in the US and Europe (<https://ieeexplore.ieee.org/document/8384857> - subscription required)
- Continuous Climb Operations with Minimum Fuel Burn (Continuous Climb Operations with minimum fuel burn)
- Efficient Climb and Descent Benefit Pool (<https://ieeexplore.ieee.org/document/6096003> - subscription required)
- Estimating ATM Efficiency Pools in the Descent Phase of Flight (Estimating ATM Efficiency Pools in the Descent Phase of Flight.pdf)
- Fuel and Emission Benefits for Continuous Descent Approaches at Schiphol (ICRAT\_2019\_Paper\_91)
- Have Descents really become more Efficient ([www.atmseminarus.org/seminarContent/seminar12/papers/12th\\_ATM\\_RD\\_Seminar\\_paper\\_17.pdf](http://www.atmseminarus.org/seminarContent/seminar12/papers/12th_ATM_RD_Seminar_paper_17.pdf))
- Investigating Benefits from Continuous Climb Operating Concepts in the National Airspace System ([www.atmseminarus.org/seminarContent/seminar11/papers/501-McConnachie\\_0126150628-Final-Paper-5-7-15.pdf](http://www.atmseminarus.org/seminarContent/seminar11/papers/501-McConnachie_0126150628-Final-Paper-5-7-15.pdf))
- Fuel and Energy Benchmark Analysis of Continuous Descent Operations ([www.atmseminarus.org/seminarContent/seminar11/papers/395-Fricke\\_0125150225-Final-Paper-5-7-15.pdf](http://www.atmseminarus.org/seminarContent/seminar11/papers/395-Fricke_0125150225-Final-Paper-5-7-15.pdf))
- Measuring vertical flight path efficiency in the National Airspace System (<https://arc.aiaa.org/doi/pdf/10.2514/6.2009-6959> - subscription required)
- Towards a common analysis of vertical flight efficiency (<https://ieeexplore.ieee.org/document/7486368> - subscription required)
- Vertical Efficiency in Descent Compared to Best Local Practices ([www.atmseminarus.org/seminarContent/seminar13/papers/ATM\\_Seminar\\_2019\\_paper\\_42.pdf](http://www.atmseminarus.org/seminarContent/seminar13/papers/ATM_Seminar_2019_paper_42.pdf))

### Stakeholder resources:

- <https://www.easa.europa.eu/document-library/acceptable-means-of-compliance-and-guidance-materials/reg/atco---air-traffic-controllers>
- European Aviation Environment Report (EAER) – <https://www.easa.europa.eu/eaer/>
- Fly Quiet and Green (FQG) - <https://www.heathrowflyquietandgreen.com/>
- Noise management at EFHK - <https://www.youtube.com/watch?v=uDI2g98o4Dk&t=48s>
- Sustainable Aviation - <https://www.sustainableaviation.co.uk/wp-content/uploads/2018/06/A-Guide-to-CDOs-Booklet1.pdf>
- DFS films including “New RNAV STARs with constraints in Germany” - [https://www.dfs.de/dfs\\_homepage/de/Presse/Mediathek/](https://www.dfs.de/dfs_homepage/de/Presse/Mediathek/)
- Noise from Arriving Aircraft: An Industry Code of Practice - Noise from arriving aircraft: an industry code of practice)



## APPENDIX Q: CASE STUDIES

### **KEY MESSAGE**

**The following case studies provide illustrative examples of practical implementation of some of the good practices recommended by the European CCO / CDO Task Force and detailed in this Action Plan.**

These case studies detail the experiences of stakeholders who implemented some of the concepts or good practices that are promoted in this Action Plan. They include:

- The implementation of CDO from top of descent;
- Essential ATCO / Flight Crew collaboration for a successful airspace change implementation;
- The LoA review process;
- The development of seasonal LoAs;
- The performance impacts of CCO / CDO performance monitoring and Flight Crew feedback; and,
- The delivery of fuel saving benefits from the airline perspective.

### **Q1: Seasonal LoA (Skyguide, Switzerland)**

Prior to 2017, operators into Swiss airports frequently requested to stay at their cruising FL for as long as possible in order to minimise the time spent at non-optimal cruising levels and therefore minimise fuel consumption. However, this was not possible due to several operational and technical limitations.

Skyguide undertook a safety analysis on the arrival routes, the conclusions of which established that LoA constraints on flight paths bring a safety benefit only when the sector capacities create delays. In other words, in low traffic periods (e.g. winter), LoA constraints have no impact on safety, so the LoA constraints could be reduced (i.e. raised) in order to better satisfy the needs of the airspace users, allowing them to fly at higher levels and reduce fuel consumption.

This analysis resulted in the creation of dynamic LoAs between Geneva ACC/APP and Marseille ACC (effective 13 September, 2018) whereby two sets of exit level constraints were defined, one applicable in the Winter season and one in the Summer season (see Table 14 for XFL parameters).

ATS Route	COP	Flight level allocation		Special conditions
		Summer	Winter	
UM623 (MEDAM – VEVAR – BARSO)	VEVAR	FL330	RFL	Max FL for Arr LFKC / LFKB / LFKS
UY24 (VEVAR – NIZ)		FL290	FL330	Max Arr for LFMD / LFMN / LFMF / LFTZ and LFMC / LFTF / LFTH
UN869 (MILPA – NINTU – MEBAK)	NINTU	FL330	FL370	Max FL for Dep Zurich list (except EDNY / LSZR at RFL) / Basel group / LSZA
UN853 (OKTET – IRMAR – BLONA – KINES)	IRMAR	FL340	RFL	Max FL for Arr Stuttgart list / LFST. This flow has the most potential fuel gain (up to 6000ft for 20min) according to 2017 figures

**Tactical shortcuts to BALS1 are usable for Geneva ACC above FL245 without coordination on condition traffic is in level flight no later than abeam GIRM (35 nm BALS1).**

**During summer period (from last AIRAC March until first AIRAC November) Geneva ACC may climb such traffic up to FL350 without verbal coordination if steady over GIRKU/NINTU.**

**During winter period (from first AIRAC November until last AIRAC March) Geneva ACC may climb such traffic up to RFL without verbal coordination if steady over GIRKU/NINTU.**

Table 14: Winter and summer FL allocation scheme examples (Effective September 13, 2018)

The LoA excerpt in Table 14 is not exhaustive and does not represent all existing agreements with similar purposes. The agreement goes to show how altitude increases can be achieved by adjusting LoAs with neighbouring ACCs. With this change, the service to operators was improved significantly in terms of fuel savings and reduced CO2 emissions.

## Q2: CDO Implementation – the HTO Project experience

### Background

The HTO project began in 2013 with the idea of developing a CDO out of cruising altitude in core European airspace for arrivals at Frankfurt airport, and finished with its implementation in 2016. The HTO project also tells the story of how an implementation project was marked by unexpected problems and lack of acceptance on both sides (Flight Crews and ATCOs) from the very beginning. An enormous amount of commitment from the project participants was needed before a significant improvement in the application could be detected by the end of 2019.

### Introduction

The “Optimised Flying” initiative was launched by DFS together with major German airlines (Lufthansa / Condor) with the aim of improving the overall benefit of DFS services for the airlines. At various meetings, it became clear that the optimisation of vertical flight profiles (CDO) with the focus on a later descent, could generate significant economic benefits for the airlines from fuel savings and for the environment through the resulting reduction in CO2 emissions.

In order to improve on the tactical vertical flight profiles (descend at your own discretion) which were already in use, and to measure potential savings, a trial was planned for 2013 / 2014, which included approaches to EDDF (Frankfurt airport) from the South / South-East, as a first step.

After the trial and as a result of the meeting between the “Optimised Flying” Working Group and representatives of the airlines on 17 July 2013, these outcomes emerged:

- The results of the trial clearly showed the limits of the feasibility of a CDO in the increasingly complex airspace structure surrounding Frankfurt Airport. The lead times required for a decision for or against a tactical descent at own discretion were too long in such complex airspace;
- The result was that most of the flights cleared for a late descent were ultimately only kept free of their points of conflict with an extremely high descent rate and / or with alternative heading instructions;
- For this reason, the responsible sector family at Langen ACC changed the existing route structure to enable new CDO and CCO procedures for a large number of flights to and from Frankfurt;
- The development of the EMPAX STAR and the associated HTO procedure and the foundation of the HTO project group, consisting of two ATCOs, two Lufthansa Pilots, one from Condor and a Project Manager; and,
- From the very beginning, the aim of the project was to enable a CDO from cruising altitude until the handover to APP in a virtual airspace tube while ensuring procedural separation to virtual departure tubes (making an increase in sector capacity possible).

Other longer-term objectives included the idea of developing a single sector or a dynamic ATC sector controlling an aircraft as it descended on the STAR, together with guidelines on how to give a descent clearance through multiple sectors – at present the HTO project was the only way that this could be achieved.

The EMPAX STAR can be found in LANGEN ACC – Sector Family 04, KNG (König) Sector and has three waypoints XINLA – XOR-BO – ADNIS before control is transferred to EDDF APP between waypoints ADNIS and PSA at FL100.

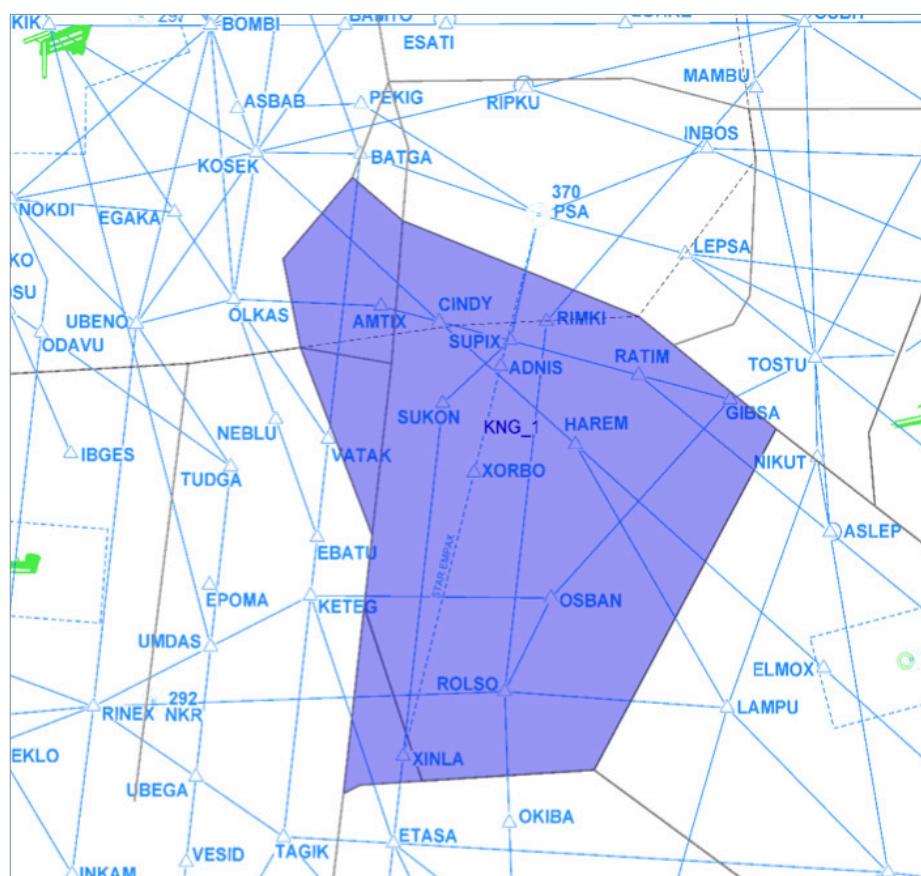


Figure 75: EMPAX STAR from XIN-LA to PSA

The “HTO Procedure” project comprised six phases:

- 1) Developing ideas for a STAR and a SID with constraints and preparation of HTO Demonstration Flights (including simulation);
- 2) Implementation / evaluation of HTO Demonstration Flights;
- 3) Preparation of the 2nd HTO Large Scale Demonstration;
- 4) Execution / Evaluation of the HTO Large Scale Demonstration;
- 5) Preparation for HTO regular service; and,
- 6) HTO regular service.

## Phase 1: Development of a STAR and a SID with constraints

There was one main goal of the project: to enable procedural vertical separation with constraints (see below).

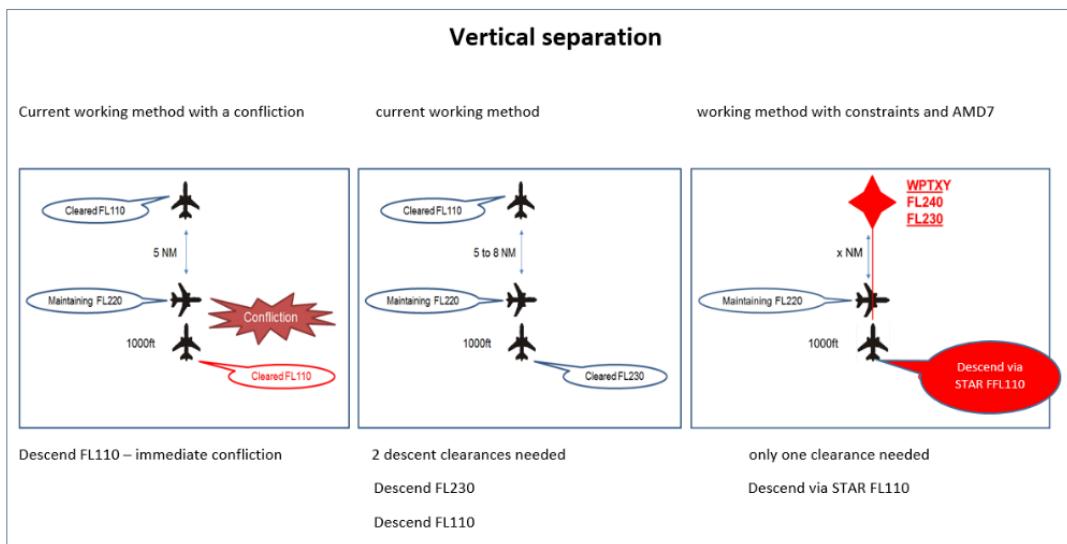


Figure 76: Working Method change proposal from the HTO Project

The first draft of a STAR was created with constraints for a CDO out of cruising altitude, from the boundary of Switzerland to the transfer point PSA (transfer from ACC to APP).

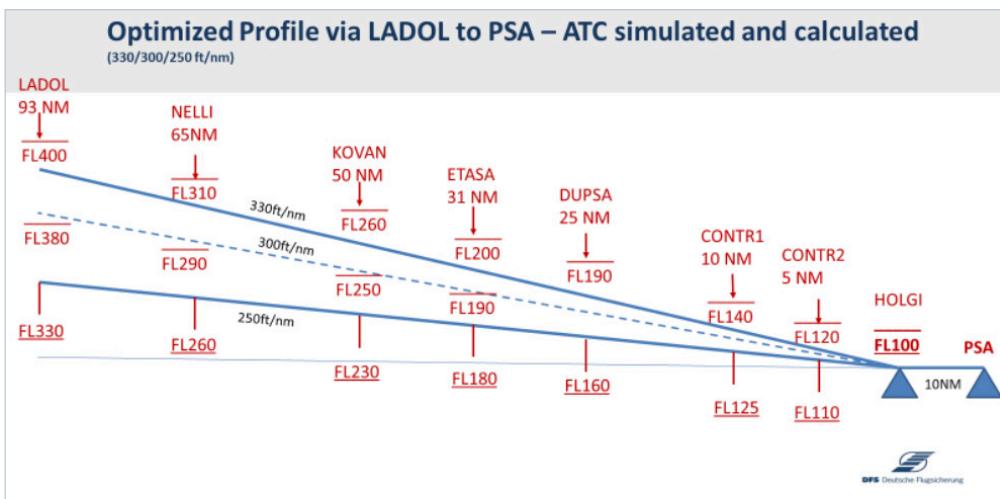


Figure 77: Planned arrival Tube RWY25L EDDF

Likewise, the first draft of a SID was created with constraints for a CCO for EDDF RWY18 out to FL210+ (see Figure 78).

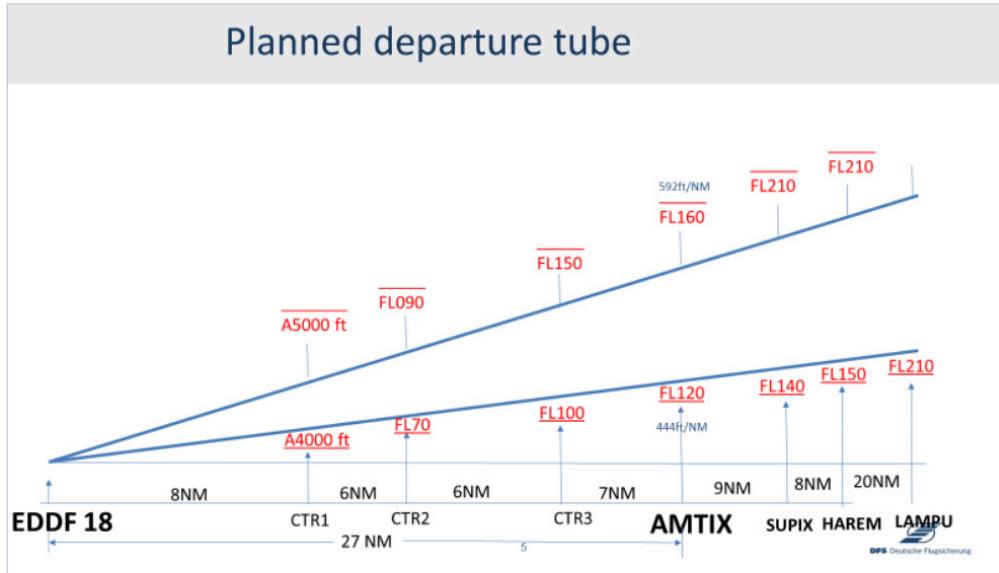


Figure 78: Planned Departure Tube from RWY18 EDDF

This resulted in the STAR being procedurally separated from the SID with departures climbing over arrivals (see Figure 79).

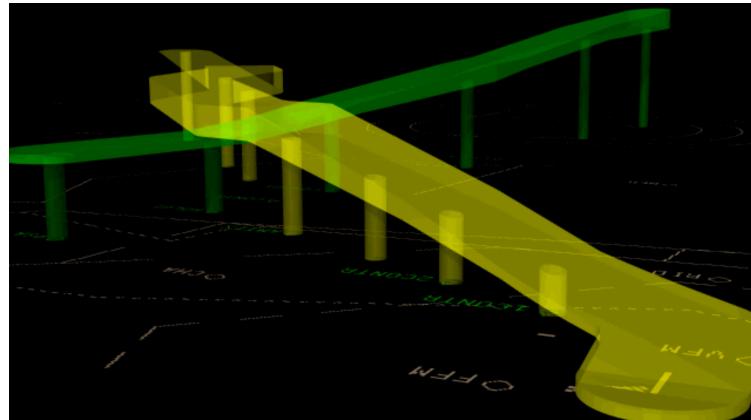


Figure 79: EDDF planned RWY25L STAR (in green) and planned RWY18 SID (in yellow)

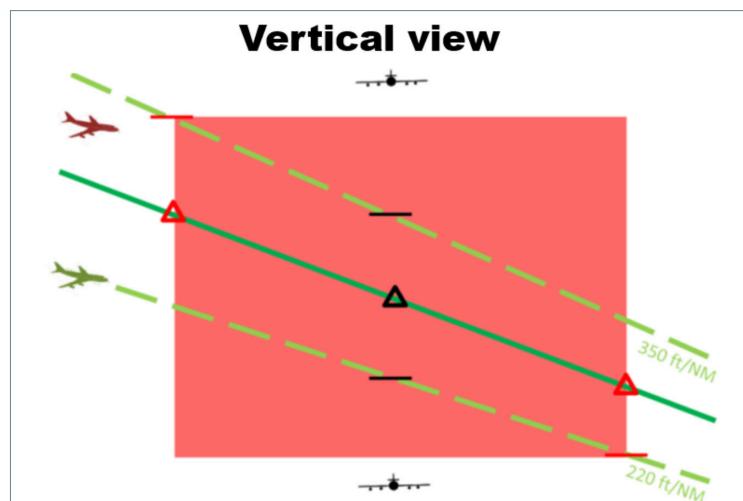


Figure 80: Vertical view of the STAR arrival tube

The next step was to solve the issue of crossing airways. From ETASA to PSA, there were three crossing airways: Z12, Z54 and Z818.

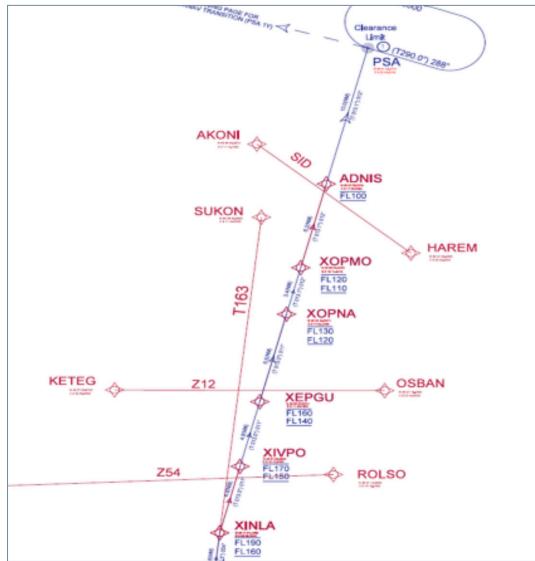


Figure 81: STAR details with crossing airways and RWY18 SID

The optimum profiles of aircraft arriving on RWY25L were assessed, modelled and simulated in accordance with the air-space design guidance in ERNIP Part 1, using different descent gradients of aircraft types that regularly flew the descent into Frankfurt. This allowed them to develop a 'tube' STAR with a series of altitude windows varying between 6000ft (FL290-350) at EMPAX (75nm to PSA) and 1000ft (FL110-120) at XOPMO (16nm to PSA).

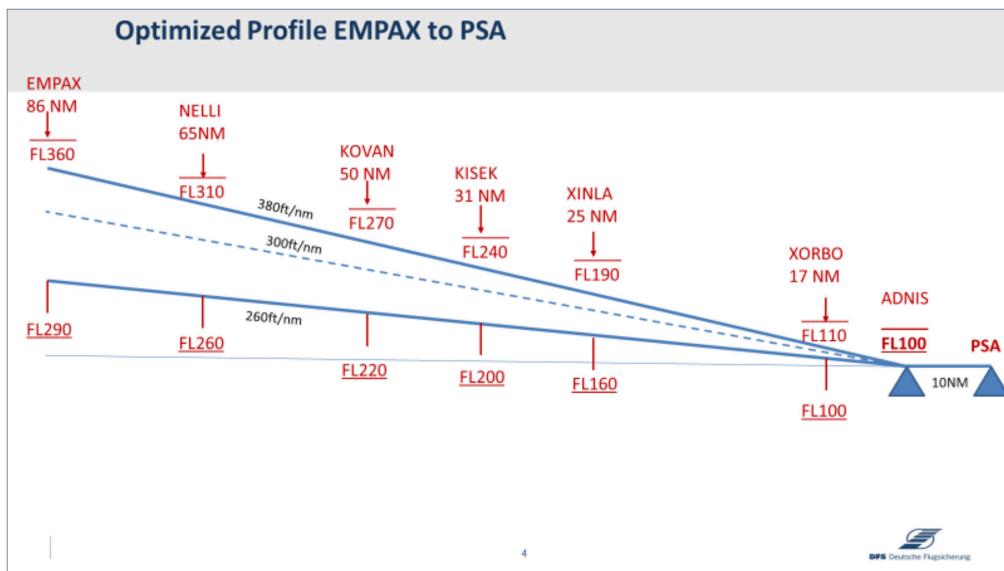


Figure 82: EMPAX STAR

Following the development of the EMPAX STAR, it was decided that the project would focus only on the arrival tube with the departure tube to be addressed at a later date.

A major issue was also raised: **there was little acceptance of the procedure by the operational ATCOs because of a general lack of understanding. It was at this point that the project members recognised the great importance of obtaining 'buy-in' from the ATCOs on the new procedure.**

While Flight Crews had been involved in all previous developments, focused collaboration between the ATCOs, who were to facilitate the procedure, and Flight Crews, who were flying the procedure, was an essential element in the successful operational implementation.

One of the main conclusions of the project was that ATCOs and Flight Crews should be very closely involved in all phases of new arrival procedure design in order for it to succeed.

## Phase 2: Implementation / evaluation of the HTO Demonstration Flights

The first part of phase 2 was to undertake a set of demonstration flights:

- A one-month phase of demonstration flights was undertaken with Lufthansa and Condor, starting on 5 March 2016;
- These demonstration flights took place from Monday to Friday from 05:00 - 08:00;
- There was a maximum of six flights per day;
- Lufthansa / Condor briefed each individual Flight Crew on the procedure;
- DFS also informed the ATCOs concerned individually, about the procedures to be applied as well as the participating aircraft (Karlsruhe, Langen, EBG 02, 04 and 10);
- DFS ATCOs completed a feedback form immediately after each flight (with special attention paid to altitude window compliance);
- The crews of Lufthansa and Condor passed on their feedback to the appropriate contact people in their group; and,
- The new track could be displayed by ATC on the radar screen via hotkey, including the FL windows.

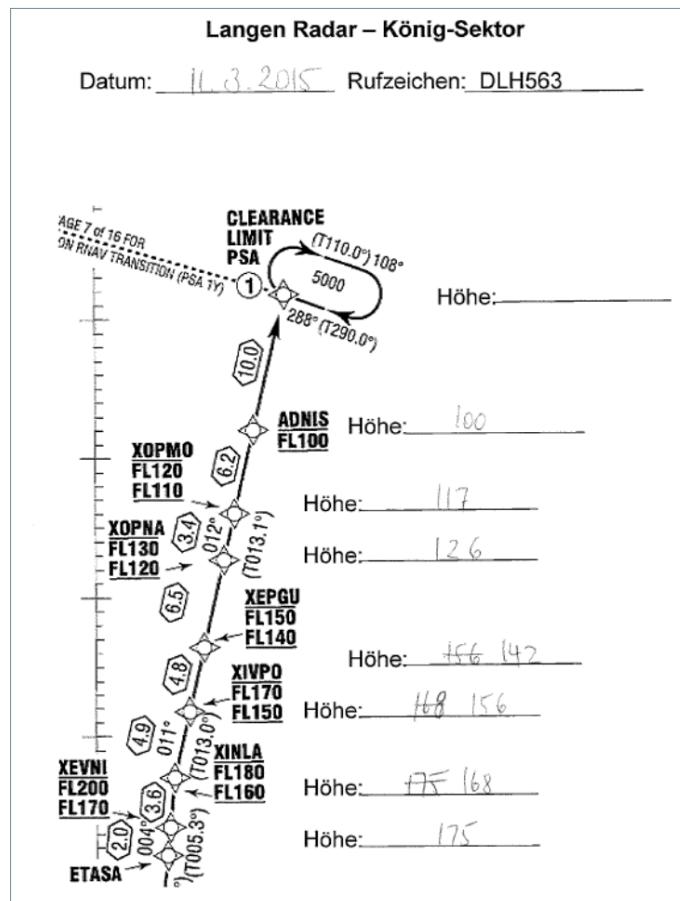


Figure 83: Example of individual flight feedback form for altitude window compliance

The first HTO demonstration flights took place between the 5th March and the 1st April 2015, with the participation of Karlsruhe UAC and Langen ACC as well as Lufthansa and Condor, based on individual air traffic control clearances. However, these demonstration flights did not produce the expected results, as DFS observed that only 43% of the flights complied with all altitude restrictions. Because of the observed result with many FL mistakes (level busts) a second, much more detailed Demo Flight phase was planned for August 2015.

### Phase 3 Preparation of the 2nd HTO Large Scale Demonstration

The second set of HTO demonstration flights were conducted between 05:00 and 09:00 local time between 24th August and 6th September 2015 and again involved Karlsruhe UAC and Langen ACC as well as the airlines, Lufthansa and Condor. They were given individual ATC clearances for the procedure. In order to prepare for this second set of Demonstration Flights, DFS sent the participating airlines coding data, including conditions for use of the procedure, one month in advance. Both airlines agreed to the requirements set by DFS for the use of the coding data.

These conditions for use included the following:

- a) Airline XY gives consent to the use of the coding data without the execution of the "Ground and Flight Validation".
- b) Airline XY undertakes to comply with the restrictions (lateral / vertical / speed) in the coding data.
- c) Airline XY forwards the coding data to a database provider to produce the databases.
- d) Airline XY is responsible for ensuring that the coding data is only available within the framework of a "tailored database" in the aircraft intended for the tailored database.
- e) Airline XY is responsible for ensuring that the coding data is not coded as a "standard database" by the database provider.
- f) In the event that the above-described "tailored database" with the coding data is also available in aircraft that do not participate in the flight tests, Airline XY shall ensure that the coding data is not used by these aircraft.
- g) Airline XY undertakes to hold the corresponding training courses / briefings before using the coding data.
- h) Airline XY undertakes to enter the ATS route T163 in flight plan field 15.
- i) Airline XY undertakes to enter the following PIN assigned by DFS in flight plan field 18: DLH: RMK/CDODLH05, Condor: RMK/CDOCFG06

The second HTO demonstration flights were also carried out, based on single air traffic control clearances. Lufthansa and Condor sent DFS a list of their planned flights. Karlsruhe UAC then sent an individual air traffic control clearance for each flight by e-mail to the respective airline. This single air traffic control clearance had to be issued by the ATCO on the day of the participating flight by radio to the Flight Crew. The Flight Crew had to report back to the Controller that (s)he was familiar with the procedure.

### Phase 4: Evaluation of HTO Large Scale Demonstration

The second HTO demonstration flight trials were evaluated by these criteria:

- Number of flights taking part in the trial;
- Minimum requirement: 68 %;
- Number of entries in the flight plan field 18;
- A requirement from DFS's letter to the customer and the customer's consent;
- Lateral compliance with trajectory (XTT (Cross Track Reference) compliance): minimum requirement 95%; and,
- Compliance with the vertical height specifications taking into account the waypoint tolerance: minimum requirement 95%.

On the 7th August 2015, Lufthansa registered 134 flights and Condor 10 flights for the trials. On the 20th August 2015,

Lufthansa registered nine additional flights and cancelled two for internal reasons. Lufthansa therefore registered a total of 141 flights plus 10 Condor flights, 151 flights in total, for the trials. Out of these flights, 124 out of the 151 flights received the clearance to descend on the STAR (as 27 flights were not cleared by the Controller to descend on the STAR on the days of the trial for exceptional reasons):

- Fifteen flights could not be cleared due to traffic;
- The crews of Four further flights had not been briefed on the project;
- Three flights were assigned a direct routing by the Controller;
- Two flights were given a different routing (via ASPAT) and for this reason the transition was not flown; and,
- The Pilot of the last flight rejected the transition.

According to ICAO specifications, an XTT (cross track tolerance) of 1nm left and right of the nominal track was set up around the EMPAX trajectory. An evaluation of the lateral compliance of the trajectory within the XTT using FANOMOS showed that

all 124 flights (100%) flew within the tolerance limits according to their release by the ATCO.

In order to evaluate the compliance with the vertical height restrictions, the first step was to examine whether the flights complied with the vertical restrictions at the respective waypoints with a tolerance of +200ft (upper constraint) and -200ft (lower constraint). For example, at waypoint EMPAX (altitude window FL290-360), the flight met the altitude requirement if it had an altitude of between FL362 and FL288.

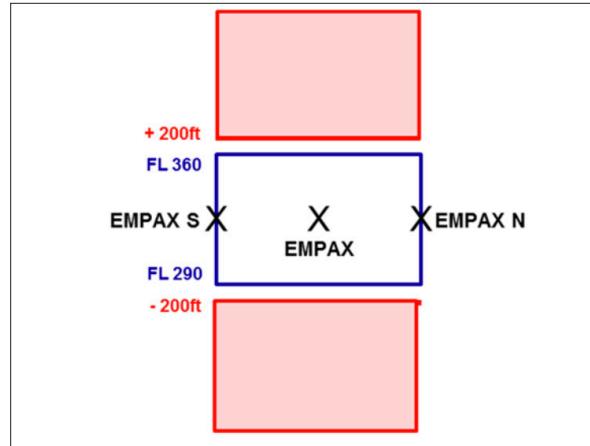


Figure 84: Height setting display waypoint tolerance

Taking into account the waypoint tolerance, it was found that 122 of the 124 flights cleared for the trial complied with all FL restrictions at the waypoints with a tolerance of +/- 200ft. This resulted in a 98% compliance figure compared to a 43% compliance figure in the first set of Demonstration Flights.

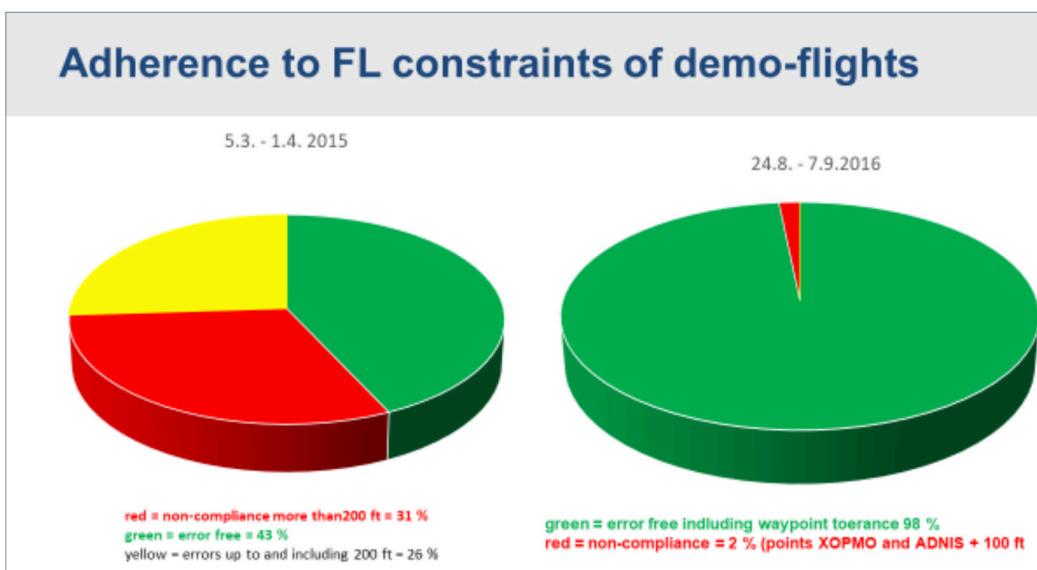


Figure 85: A comparison between the altitude window compliance for the first and second set of Demonstration Flights

After the Demonstration Flights were completed, these points were taken into consideration:

- The EMPAX Transition became the EMPAX STAR;
- The original Airway T163 remained intact – (navigational requirement, as a STAR can only be flown by aircraft equipped with RNAV1. The minimum requirement in Germany is RNAV5);
- The introduction of the EMPAX STAR into regular operation commenced on 18th August 2016;
- Airlines were requested to file the EMPAX STAR, whenever RNAV1 equipped, on their approach charts via 'Remark'; and,
- The procedures would be analogous to the Demonstration Flights.

However, a couple of critical points remained. As things stood, it was not allowed to separate EMPAX STAR traffic from other traffic by using FL constraints. In addition, an issue was also found with the Selected FL conflict warning in the cockpit. According to a meeting of the ODP Project, the FMS (contrary to the experience made with the Demonstration Flights) would comply with the lower FL of the next constraint and not the actual cleared FL in the FMS. This generated a mismatch warning (mismatch between cleared FL and FMS selected FL). A systemic solution on the side of ATC would be very challenging and time intensive. Technically, you could enter a level band, where the lower FL would correspond to the cleared FL and the upper FL could be an arbitrary FL beyond the actually flown level.

The next step to be followed was the development of a safety assessment for flights to EDDF via the EMPAX STAR. This was mandated due to the change in the ATCO working method because of the new procedure, together with the resulting risks that are an integral part of the safety assessment. The change was notified to the BAF (Federal Supervisory Authority for Air Navigation Services).

The Functional Hazard Analysis (FHA) of the safety assessment revealed three hazards, which could lead to four effects on air traffic safety. For these hazards, safety objectives and, where appropriate, safety requirements were identified. Within the framework of the safety analysis, this risk situation was determined, considering the safety requirements:

Risk Category	a	b	c	d
Number of risks after implementation of all safety requirements	0	0	0	12
Number of risks after 2 <sup>nd</sup> validation	0	0	0	16

Table 15: Risk classification

To conclude the safety assessment, only acceptable d-risks were identified. No further hazards were identified in the first validation. The evaluation of the existing hazards was slightly adjusted because of new findings. However the risk classification remained unchanged and only acceptable d-risks continued to exist. Thus, the present adjustments corresponded to a minor revision and included the shortened signature procedure.

The safety assessment will be re-validated in the next years, as there is a four-year period of validity. Should a change be made to the target status in the meantime (or should there be a significant increase in safety-related incidents), an early revision of the existing safety assessment would become necessary.

During the familiarisation phase (at least one month from the commissioning of the change), accompanying monitoring was carried out by analysing operationally relevant incidents (such as daily report entries or reports to the reporting system). In particular, any Selected Altitude Alerts (ATCAS) and LVL Bust Warnings (VAFORIT) as well as the compliance of the aircraft with the altitude constraints, had to be taken into account and evaluated in the monitoring and measures required. If new aspects arose which had not already been considered in the safety assessment, an immediate assessment had to be carried out and, if necessary, appropriate risk minimisation measures initiated at short notice.

As the FL constraints were increasingly not being met by aircraft following the first operation of the EMPAX CDO, monitoring was extended. Since Autumn 2017, monitoring has continued to be carried out every month for two weeks (Mondays

to Fridays) in order to assess whether measures taken lead to an improvement in compliance with the altitude constraints.

If a descent from an intermediate altitude without further descent clearance resulted in an acceptable risk, operational monitoring had to be carried out until further notice by closely observing this behaviour on the EMPAX STAR. If such events occurred, the safety assessment was to be re-validated immediately.

The Langen and Karlsruhe ACCs planned to introduce the STAR for approaches to Frankfurt coming from the south, starting from the route point EMPAX. This was intended to offer the customer and the ATCOs a descent profile that would lead to an improvement in horizontal flight efficiency, fuel consumption, CO2 emissions and communication between the ATCO and the Flight Crew, while at the same time increasing predictability for the Flight Crew and the ATCO. The traffic flow to be adapted (the current T163 route) would result in 2nm of distance flown savings per flight together with the savings from optimising the vertical profile.

Flights from the South were formerly processed by the TGO (Tango) sector of Karlsruhe ACC when entering German airspace and descent from cruising altitude was initiated in this sector. After passing FL235, the aircraft would move into the area of responsibility of the Langen ACC, first into the LBU sector (Luburg), then through the KNG sector (König). This sector would then transfer the aircraft at the point PSA to the Frankfurt APC.

On the new EMPAX STAR, the flights follow the path of the previous ATS route, T163, to point XINLA and from there follow the new route directly to PSA. In order to be able to map the flight tracks in the FMS of an aircraft, it would be necessary to publish height windows on waypoints along the ATS route T163. This is currently not technically feasible in the FMS.

For this reason, the waypoints of the new route, up to the point XINLA, had to be stored in the FMS as a different entry route (EMPAX STAR), since FL constraints could be programmed on such a STAR.

Both the lateral course of the STAR / Initial Approach segments stored in the FMS and the vertical profile defined by FL windows from EMPAX to ADNIS corresponded to the previous flown flight path of arrivals from the South.

From PSA, the EMPAX STAR follows today's transitions, but ends at the IAF DF644 (RWY07R) or DF616 (RWY25L). In the absence of an approach clearance by the Controller, the aircraft continues its final approach independently at the IAF in accordance with the corresponding ILS procedure.

One ILS procedure per operational direction (for RWY25L and RWY07R) is connected to the new EMPAX STAR with a new initial approach segment. When using the EMPAX STAR, only one ILS procedure is available per landing direction.

The NL Upper sector receives information about the landing direction from the NL Mitte sector (call Langen LBU Sector to Karlsruhe TGO Sector). The Controller in Karlsruhe checks whether he can clear an aircraft for the EMPAX STAR as a "CDO". For these flights, he must check whether the original flight plan contains the EMPAX STAR or alternatively ask the Pilot. Only then may he clear the procedure. If the Controller does not give clearance for the EMPAX STAR, the flight follows the EMPAX laterally to the flight of the STAR and leaves the altitude only after clearance by the Controller in accordance with the issued descent clearance.

The NL Upper releases the flights by default to the upper-middle airspace boundary (FL 240). No information is required at Langen, since the flight is not cleared vertically beyond the border of the Karlsruhe area of responsibility (ZB) and the Controller in Langen must check in any case whether he must clear the flight in his ZB according to CDO conditions or conventionally on the STAR. Langen informs Karlsruhe in good time if, for traffic reasons or unavailability ILS for individual flights or for certain periods, no CDO approvals are to take place.

Langen accepts that the flights will be handed over either on the STAR descending FL240 procedure or tactically at waypoint KOVAN at FL 240 (non-coordinated; LoA procedure). The clearance of the STAR including altitude constraints is marked

in Langen on the strip in sector PSS, so the downstream sector knows whether the CDO clearance has already taken place. The clearance must be granted for each new sector.

The LBU sector in Langen will then transfer the approaches to the KNG sector descending to FL150. The transfer level from the KNG sector to Approach EDDF will be changed from FL110 to FL100. For intersecting traffic, the clearance is limited to an intermediate FL to ensure separation.

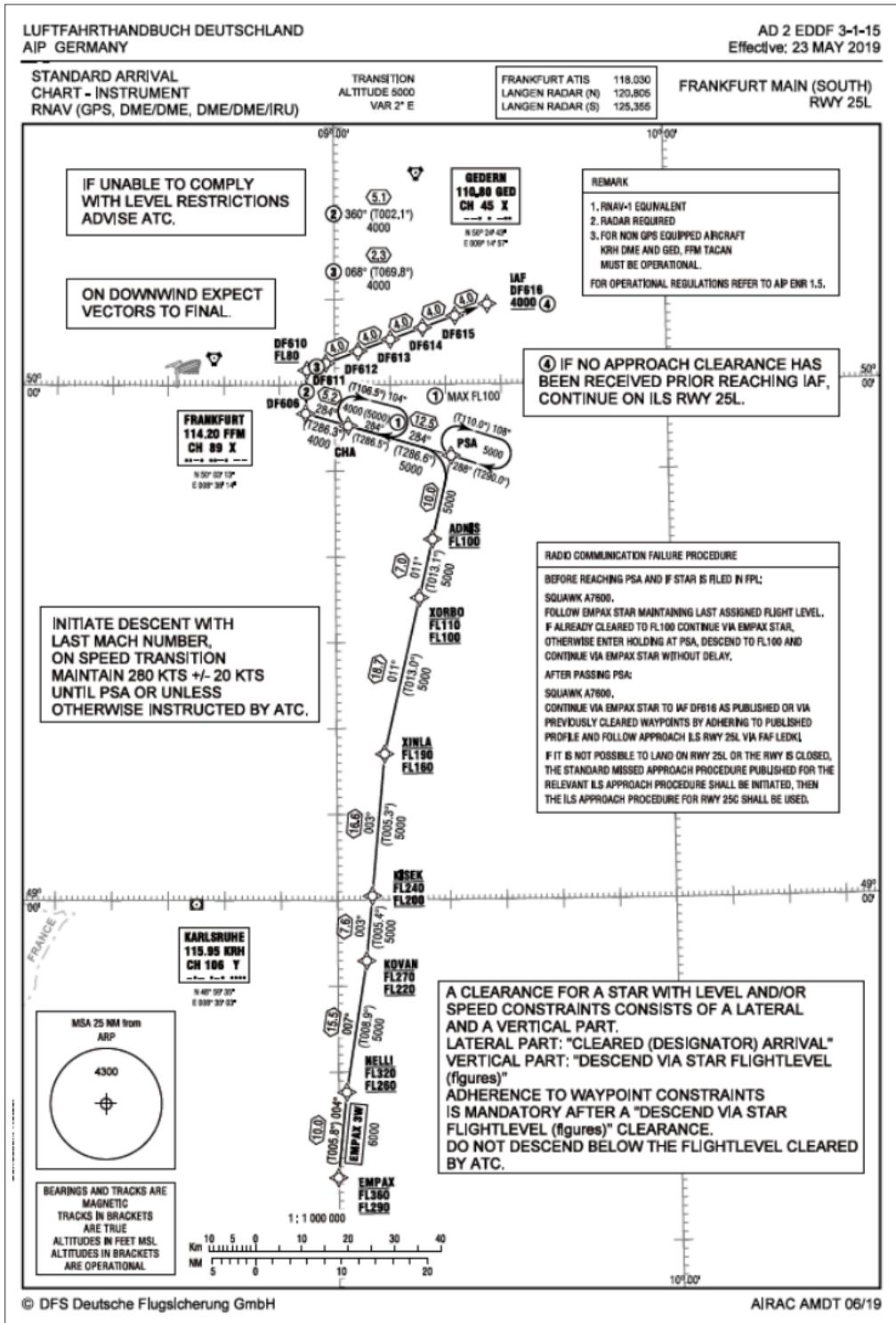


Figure 86: Latest published EMPAX STAR (23rd may 2019)

## Supporting Information

**In order to prepare for the Demonstration Flights, airlines sent out crew briefings to explain the procedure. The messages below were included in the crew briefing material (adapted for the English language):**

*Ladies and gentlemen, dear Colleagues,*

*"Flying at low altitudes leads to increased fuel consumption". A component of every solid training is the descent planning.*

*Due to the high traffic levels at the main hubs and "en-route" it has become less and less possible in the past years to arrange the descent as it would have been desirable on the day due to aircraft type, weight, descent speed, wind etc.*

*In order to safely control air traffic, ATC has to agree standardised transfer altitudes, allocate fixed descent rates and regularly force aircraft to fly at lower than optimum altitudes. This avoids delays and maintains airspace capacity.*

*As an airline, we are in constant contact with ATC in order to agree sensible regulations. We want to improve flight efficiency without having to accept a large reduction in capacity. Another positive effect of the CDO (Constant Descent Operation) is the avoidance of unnecessary aircraft noise.*

*In the past, we focused on the "tactical" CDO whereby clearances are given, which open the possibility for the Pilots to arrange their descent freely. However, such clearances could only be issued rarely and restrictively, which led to frustration amongst Pilots and ATCOs. Now we will take another step and publish fixed CDO profiles, as we know them from the USA and Canada.*

*This will improve our "CDO - Performance" by defining FL windows on fixed routes for overflight points, which are cleared by Rhein Radar with the clearance "Descend via EMPAX STAR FL240". After that "continue EMPAX STAR descend FL100" by Langen Radar. This is also known from the CDA Trials at Munich.*

*DFS has now developed the first CDO procedure for Frankfurt together with Lufthansa and Condor flight operations.*

*The CDO will take place on a new approach route between the waypoint EMPAX and PSA. For ICAO compliant coding, the entire structure of the IAF and RNAV waypoints had to be rebuilt.*

*You will find the new procedure in the Route Manual and in the database of all aircraft. The clearance for the EMPAX transition between LADOL and EMPAX will be granted at Rhein Radar. Should Rhein Radar not be able to give clearance for the EMPAX transition, this will take place at the latest at Langen Radar near the waypoint NELLI. Crews are requested to complete the procedure (preferably in "Managed Mode" or "VNAV PATH Mode").*

*If corrections have to be made, it is up to the crews how they comply with the published constraints. Compliance is, of course, mandatory.*

**Another Company information sharing included a briefing on the following subject:  
“Every litre counts – CDO”:**

*Dear Colleagues*

*Last year, together with the major German airlines, we launched the “Optimised Flying” initiative with the aim of further improving the overall benefits of DFS services for the airlines.*

*It very quickly became clear that further optimisation of vertical flight profiles, with a focus on an even later descent, could generate a very high economic benefit for the airlines.*

*For this reason, a live trial for approaches via NELLI and ASPAT to Frankfurt was set up during EBG04.*

*For approaches via ASPAT, a later descent has meanwhile been included in the existing agreements between Munich and Langen.*

*The approaches via NELLI are cleared on a tactical basis for a so-called Late Descent, which should ideally be a Continuous Descent to PSA. A corresponding procedure is being tested as a standard procedure.*

*With the display in the operating room and the Info-Flyers that are in the preparation of being created, we would like to clarify again also the important meaning that this topic has for us as a company.*

*We know that we are excellently positioned in our daily Pilot work and that we have almost reached the maximum of what is possible in the area of direct routing. However, we still see potential in optimising vertical efficiency, also in the area of standardised profiles.*

*We also want to exploit these opportunities for improvement as often as possible. A fuel saving of 50 to 100kg (CO2 saving of 160 to 320kg) per flight doesn't sound like much at first glance, but if we succeed in achieving these savings with the broad mass of approaching aircraft, it will quickly turn into several tons and thus a significant savings volume for the customers.*

*Hence, the sentence was to be understood as supplementary motivation and not as criticism.*

Other work included creating ATCO briefings of which an excerpt is shown below in Figure 87 to Figure 93. This briefing focused on the introduction to the project, R/T phraseology, coordination requirements and other important information with the objective of covering all possible areas of information-sharing and obtaining buy-in from all essential actors on both the Flight Crew and ATCO sides.



Figure 87: Excerpt from ATCO briefing 1

Work is currently ongoing for web-based training for the Flight Crew side to share more information on specific issues that were encountered during the Demonstration exercises.

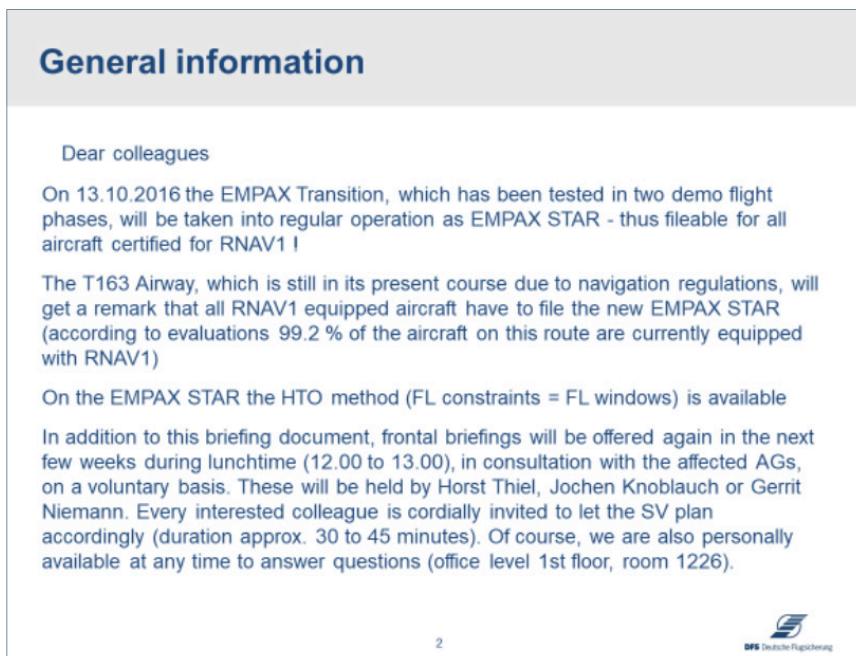


Figure 88: Excerpt from ATCO briefing 2

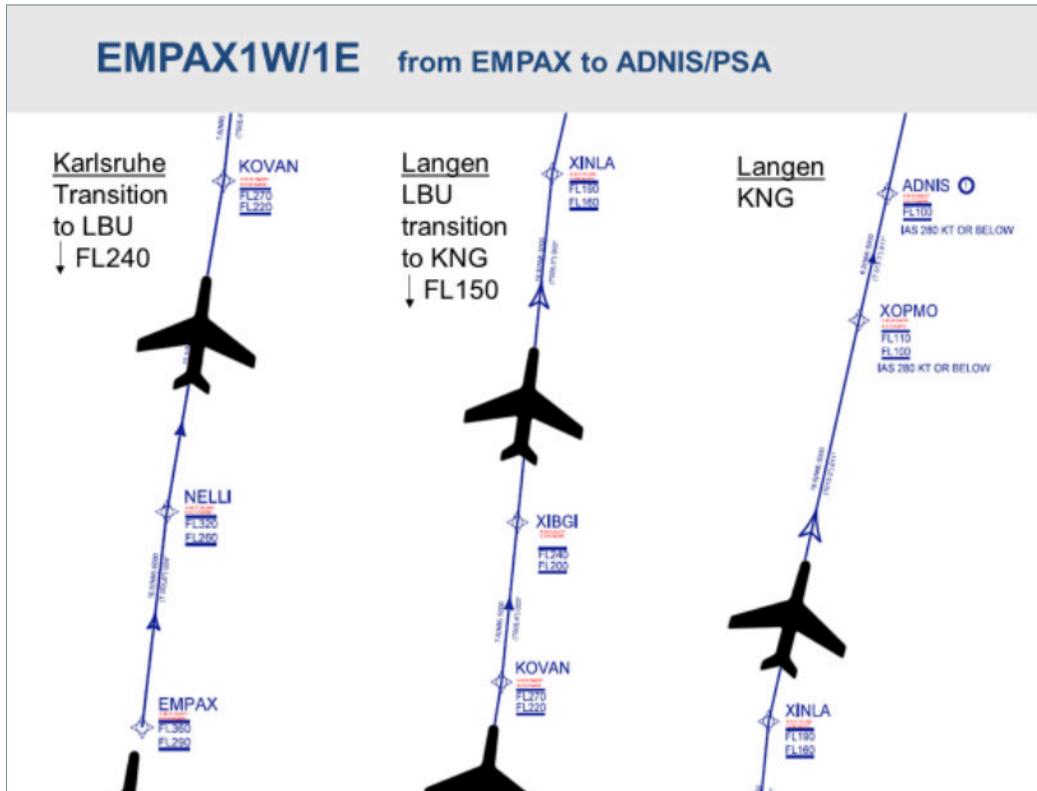


Figure 89: Excerpt from ATCO briefing 3



Figure 90: Excerpt from ATCO briefing 4

## Radiotelephony according to CDO ICAO DOC9931 (BA-FVD 852.724)

A “**descend via**” clearance may be issued on procedures with defined altitude crossing points and/or defined speeds.

A descend via clearance is an instruction to the pilot to descend in a manner that complies with the published lateral flight path, altitudes and speeds. Because lateral and vertical flight paths are known, a “descend via” clearance may be given well in advance of the actual descent point.

A “descend via” profile is known in advance to ATC and pilots, adding predictability to the procedure.

**PHRASEOLOGY**

**DESCEND VIA (designator), FL**

**EXAMPLE**

**“Descend via STAR FL150.”**



Figure 91: Excerpt from ATCO briefing 5

## Separation with and to FL constraints

- We are working at full speed on this topic
- Status today: **we are not allowed to separate with and to the FL constraints**
- From this point of view, the following therefore applies from a safety perspective: Whenever we have crossing traffic through, above or below the EMPAX tube and we do not have sufficient lateral separation, we have to work with intermediate FL and thus, if necessary, interrupt or stop the procedure - or alternatively keep the “disturbing” traffic clear of the EMPAX STAR.
- The Langen branch management is aware that under these conditions it is highly unlikely that the CDO quota can be increased, as only the possibility of separation and the associated mandatory adherence to FL restrictions promises to make work easier and thus increase capacity and CDO quota

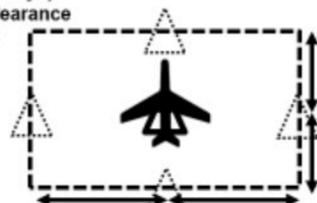


Figure 92: Excerpt from ATCO briefing 6

## Background knowledge: Navigation accuracy

The EMPAX STAR is an RNAV1 route. Therefore, at each waypoint this STAR a so-called along track tolerance of  $\pm 1.6$  NM, and a cross track tolerance of  $\pm 2.0$  NM (already applies today for all waypoints, NDB, VOR)

What does this mean for us (already today?)  
For example, do we give a plane the clearance "cross PSA FL110", so he could reach FL 1.6 NM in front or behind PSA!



<b>ATT:</b> RNAV1: 1,6 NM (GPS) RNAV5: 2,01 NM (GPS) 2,15 NM (DME/DME) 0,3-6,5NM (VOR/DME)	<b>XTT:</b> RNAV1: 2,0 NM (GPS) RNAV5: 2,51 NM (GPS) 3,30 NM (DME/DME) 2,5 - 7 NM (VOR/DME)
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Figure 93: Excerpt from ATCO briefing 7

## Phase 5: Preparation of HTO regular service

This information-sharing was also supported by other communication campaigns:

- Face-to-face meetings;
- FAQ sessions;
- Simulator training;
- Information letters; and,
- A short film.

Normally the project would have ended at this point, but it was precisely then that new issues arose. These included:

- Compliance with the altitude constraints was still found to be insufficient;
- About 10 % of all flights failed one or more of the altitude constraints because of:
  - A lack of awareness of the procedure especially the vertical procedural part;
  - Mishandling of the FMS, FMS equipage and sub-modes of FMS descent modes not clearly trained and documented;
  - Unknown meaning of the clearance "descend via" in accordance with ICAO AMDT7A phraseology;
  - Changing winds;
  - Speed reduction by ATC; and,
  - The need to comply with altitude constraints with 0ft tolerance sometimes was not always clearly understood.

Because of these factors, despite individual briefings the information-sharing and company notices on the Flight Crew side, the non-compliance led to very weak acceptance on the ATC side because:

- ATC was not allowed to procedurally separate other traffic with that procedure (next phase);
- There was very weak compliance with the adherence of the constraints;
- The fuel savings were less than expected;
- depending of the type of aircraft, savings varied between 0-150kg per flight (compared with non-HTO); and,
- FMS behaviour i.e. at FL100 reduces Speed 250kts – so point ADNIS was failed the most.

In order to rectify these failures and to try to persuade ATC to retain trust in the procedure, several change management measures were implemented. These included:

- The Flight Crew of every flight that violated a constraint were individually written to and questioned;
- Frequent Flight Crew / ATCO meetings were held for better mutual understanding (approximately 30 such events);
- Presentations of the HTO project were made at Flight Crew meetings - about 1,800 Pilots from the Lufthansa Group and Condor were reached; and,
- A design change was made in May 2019 – to make it easier to reach FL100 at waypoint ADNIS (see Figure 94 left) by increasing the distance between ADNIS and XORBO by 0.8nm.

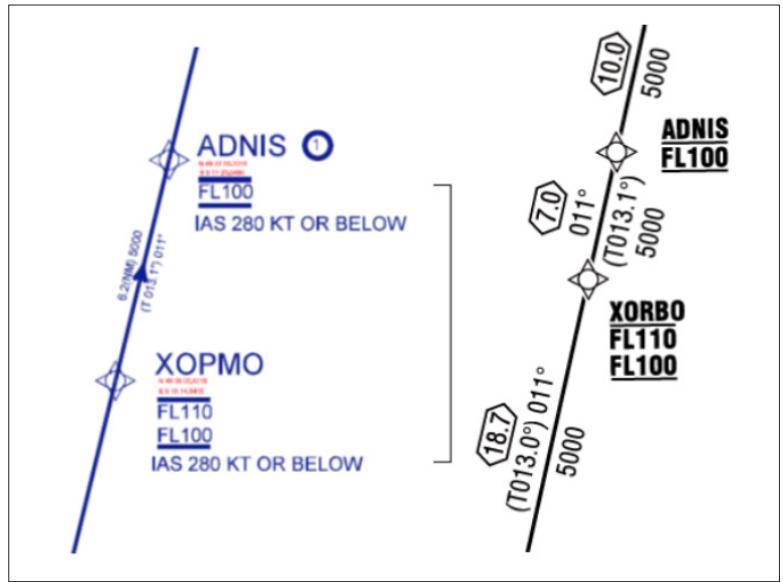


Figure 94: Design change at ADNIS increased distance between ADNIS and XORBO) to make compliance with altitude window easier

Another improvement was the presentation of the statistics on the STAR clearance rate to ATCOs, which commenced in October 2019 (see Figure 95).

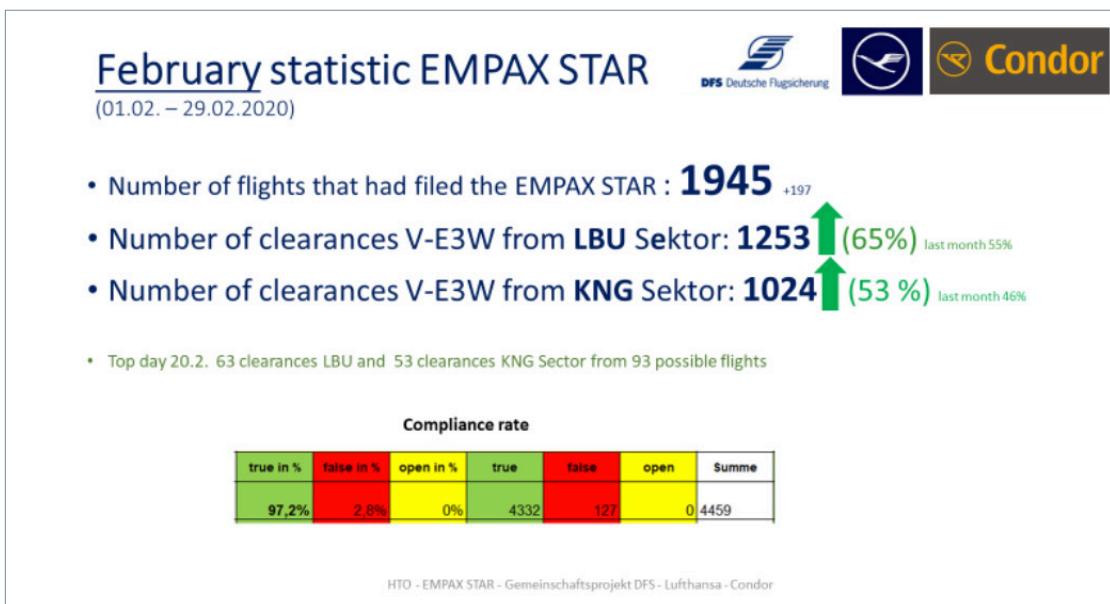


Figure 95: Statistical feedback on HTO STAR clearance rate

Despite all the problems encountered, all project participants, both from the Flight Crew / airline side and from the ATC side, still saw the potential of HTO, not only in terms of the fuel and emissions savings, but also in terms of increasing sector capacity. These benefits included:

- The possibility for a reduction in separation;
- Reduced radiotelephony, and a corresponding increase in sector capacity;
- In the best case, only one clearance from leaving cruise FL until transfer to APP;
- A reduction in the mental work required to solve problems between arriving and departing traffic – especially with a departure tube with constraints (procedural separation); and,
- Fuel saving, idle power flying, with less inefficient intermediate level segments.

With this understanding, efforts will continue to increase the acceptance of HTO by ATC as well as the compliance with flight level constraints by Pilots. As can be seen by this case study, implementing a CDO from high level is not without its challenges. However, this case study provides detailed insight into the many challenges that may arise and incorporates many good practices that are highlighted in the European CCO / CDO Action Plan. These include, but are not limited to:

- The requirement of high level collaboration with all stakeholders to understand the objectives of any airspace (re-)design project;
- **The essential need for focused and continuous ATCO / Flight Crew collaboration, cooperation and coordination in the design, development, assessment, trialling and implementation of new procedures;**
- The importance of the use of the correct phraseology;
- The importance of supporting briefing material and training material for all actors; and
- Performance monitoring and feedback.

The most important message that the HTO project would like to share is this: what the HTO Project personnel had to realise repeatedly was that it was not enough just to publish documents.

***"There is a need for dialogue with those who have to use the new procedure, the ATCOs and the Flight Crews"***

This is a challenging and long-lasting process. At the end of the day, however, the HTO project can only be successful if the constraints are strictly adhered to by all aircraft.

Once the EMPAX STAR is fully implemented, DFS plans to develop similar STARs for other Frankfurt arrival streams including cross-border STARs with neighbouring ANSPs. Work is now underway for a similar style CCO procedure for Berlin Airport.

## Q3: LoA Revision – lessons learned from ODP

The SESAR ODP project conducted a review of LoAs in the core area of European Airspace, and then went on to implement several optimisation changes and assess the impact of these changes. The process resulted in the descent profiles being raised for a number of routes, as shown in Figure 96, making for large fuel savings.

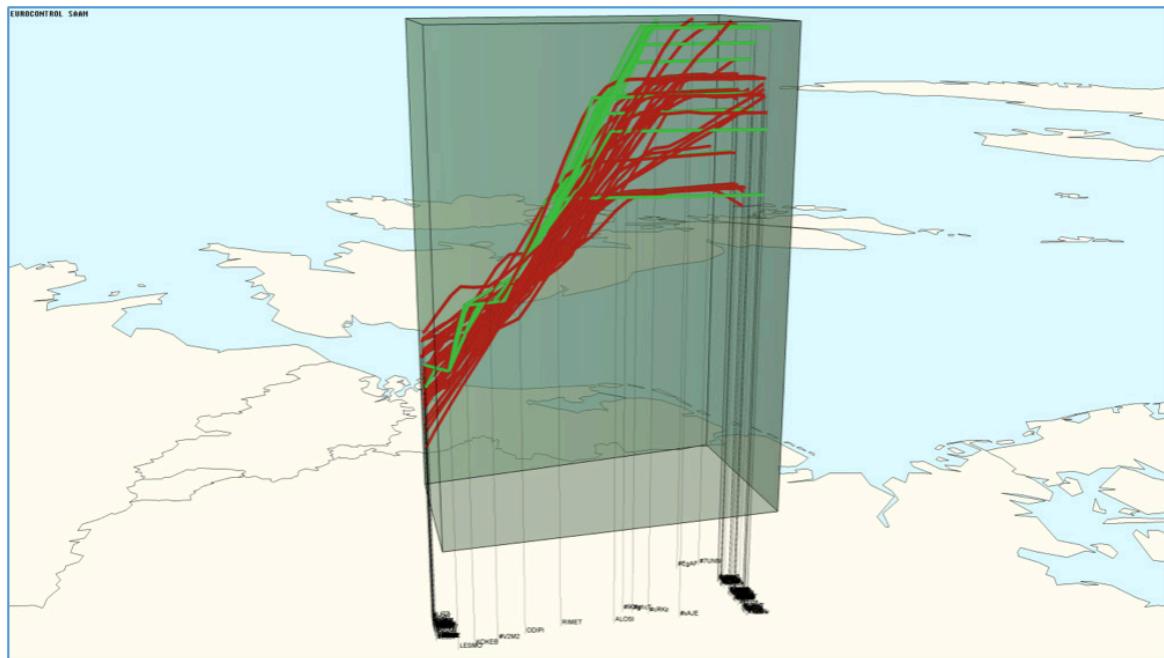


Figure 96. Reference (red) and ODP (green) radar data recordings to Frankfurt (EDDF) via RIMET

Here is a summary of the main lessons learned relating to the LoA review and corresponding updates and optimisations:

- Start descent later:  
European LoAs typically penalise aircraft by making them descend earlier than they would like to (typically 30nm to 80nm earlier). Relatively minor LoA revisions where the transfer level is raised by 2000ft. have a relatively small impact on a single AU, but when aggregated, these result in large fuel savings and environmental benefits.
- Consider prioritising arrival profiles over departure profiles:  
Airspace design in Europe is often based on making arrivals descend early, to be below climbing flows. This strategy achieves continuous descent and climb profiles, but only the climb profile is optimised; arrivals achieve a continuous but sub-optimal profile, and the extra fuel wasted by the arrivals by the early descent often offsets the fuel saved by the departures, thanks to their unconstrained profile. When revising LoAs and transfer conditions between sectors, consideration should be given to airspace design options that raise the arrival profiles, even at the expense of introducing level segments for the departures.
- Increase granularity and use system support:  
LoAs typically consider a worse-case scenario in terms of traffic load and traffic presentation. Large fuel savings can be realised if LoAs include more granularity, e.g. different transfer conditions on weekends, or during periods of low demand. Some systems (e.g. those at Austrocontrol, DFS, DSNA and Skyguide) allow the introduction of variable default transfer conditions / sector exit levels, thereby supporting Controllers so that they do not have to remember which flight levels / altitudes are applicable at different times or days of the week.

- Use modelling and involve airspace users in the process:

The assessment of the potential impact of fuel of a change to a LoA needs to be undertaken by taking into account the traffic mix that flies that route, typically through a Fast Time Simulation and / or other types of modelling activities. Airspace Users should be involved in the modelling process and in the analysis of the results and evaluation of potential options. Real Time Simulations may be necessary in order to help visualise the impact on traffic flows from the ATC point of view.

- Make speed management more predictable for the Flight Crew:

Published speed constraints improve predictability for ATCOs by harmonising traffic behaviour and may also be used to improve energy management for Flight Crews. LoA design should take into account that, during the descent, speed constraints at waypoints severely affect the angle of descent. For some aircraft, speed constraints below 230 KT are not possible in clean configuration, and therefore should not be used before the deceleration point in the approach phase.

- Keep it simple:

It is useless to agree on an optimised procedure that is not going to be applied in practice. Procedures should be designed so that they can be used at peak times, when Controllers are very busy. Transfer conditions should be kept as simple as possible, e.g. LoAs with multiple constraints on the same route increase the Controllers' monitoring workload and may be problematic. LoAs with two constraints that are too close to each other are also difficult for the Flight Crew to manage and should therefore be avoided.

- Not all LoA constraints need to be published:

Published constraints allow the Flight Crew to plan their descent accordingly. However, Controllers should waive LoA constraints whenever they are not necessary, as it would be inefficient for the Flight Crew to plan for a constraint that would not be applied in practice. Whether a constraint should be published in the AIP or not depends on how frequently it will be applied. There should be a continuous monitoring process to reassess which LoA constraints should be in the AIP. Before publishing a new constraint, it may be useful to conduct live trials in which the constraints are issued tactically by Controllers over R/T.

- For unpublished constraints, train ATCOs to share information as much as possible (bearing in mind the possible impact on R/T workload):

When a decision is made to not publish a LoA constraint, it will need to be provided tactically by Controllers to every aircraft. Controller training should make clear that an optimum descent profile under specified restrictions is only possible when the restrictions are made known to the Flight Crew as soon as possible.

- For separation, reinforce published vertical constraints over R/T:

While non-compliance with vertical constraints issued explicitly over R/T is not a common occurrence, non-compliance with vertical constraints published along a STAR and not explicitly mentioned in the ATC clearance is not so rare. Published constraints are useful in terms of organising traffic flows, but they cannot be relied upon for separation purposes unless the Controller reinforces them over R/T.

- Plan ahead:

Changes to LoAs and RAD restrictions that involve changes to published procedures follow a slow process linked to the AIRAC cycles, which may cause a delay that needs to be considered in project planning.

- Include the transition plan in your Plan.

The LoA revision process does not end when the new procedure is published or the new LoA is implemented. The project plan should include communication activities before and after the implementation and allow for a transition period, during which Controllers may need to issue the constraints over R/T, even when constraints are published.

The lessons learned are equally applicable to the revision of transfer conditions between sectors in the same ANSP.

## Q4: Performance monitoring and Flight Crew feedback – the London case:

### Performance measurement: London Case Study – The ANSP perspective

CDO usually relates to a continuous descent from cruising altitude. In the UK, CDO is more commonly known as Continuous Descent Approach (CDA), which typically starts from an altitude of 6,000 feet and is thus a subset of the noise CDO, with the primary objective of reducing noise at and around airports.

From 1994-99, the UK Government considered the feasibility of setting noise limits on arriving aircraft. Rather than imposing a fining regime, a report was published in 1999 by the Aircraft Noise Monitoring Advisory Commission (ANMAC) recommending an Arrivals Code of Practice to be published. The Code of Practice was produced to try to identify steps, which could reduce noise generated by arriving aircraft. The ANMAC document highlighted CDAs as the principle method of reducing arrivals noise. A Working Group was set up in 2000, comprising airport operators, airlines, the CAA, NATS and the Department for Transport. The first Arrivals Code of Practice was published in February 2002. Although written for the three London airports (Heathrow, Gatwick & Stansted), the Code provided broad base guidelines that could be modelled for any airport.

The overall benefits cited by the document recommending CDA were:

- Fuel savings per sector for airlines;
- Reduced environmental impact in and around airports; and
- Airports would meet their environmental targets, and this could allow future planned expansion opportunities.

The Code of Practice, when published in 2002, was in two versions: a full version and an abbreviated version, specifically designed to be used by aircrew and ATC as a quick read, rather than the fuller version. The full version contained evidence and noise data on the reduction in noise based on level flight flown.

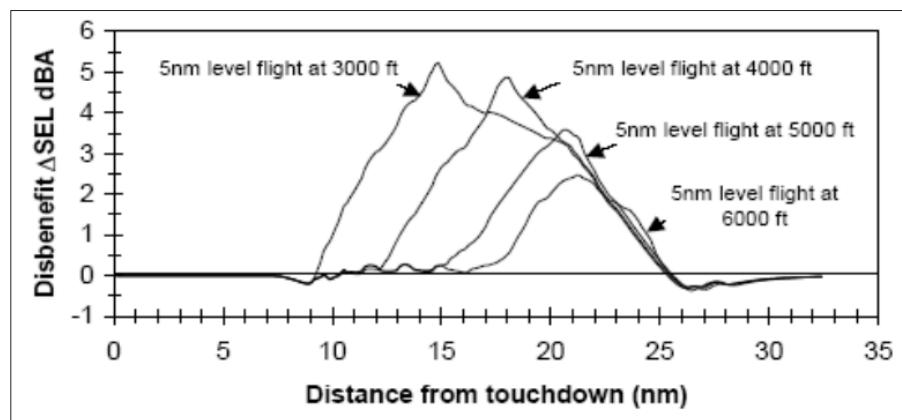


Figure 97: CDO noise benefits estimated for different distances from touchdown

There are various versions of CDA or CDO, but in the UK, the adopted definition of a CDA is:

*"A noise abatement technique for arriving aircraft in which the Pilot, when given descent clearance below the Transition Altitude by ATC, will descend at the rate he judges will be best suited to the achievement of continuous descent, whilst meeting ATC speed control requirements, the objective being to join the glide-path at the appropriate height for the distance without recourse to level flight."*

The aim of the CDA procedure is to provide Flight Crews with the ATC assistance necessary for them to fly a continuous descent on the intermediate and final approach, at speeds that require minimum use of flap etc. This has significant benefits in terms of noise produced beneath the approach area, and in the reduction of fuel used. The procedure requires ATC to apply systematic minimum speeds to inbound aircraft together with providing adequate DTG information.

After publication of the Code of Practice there was an overnight jump in CDA compliance across all three airports. In addition, it was observed that the compliance rate was seasonally dependant.

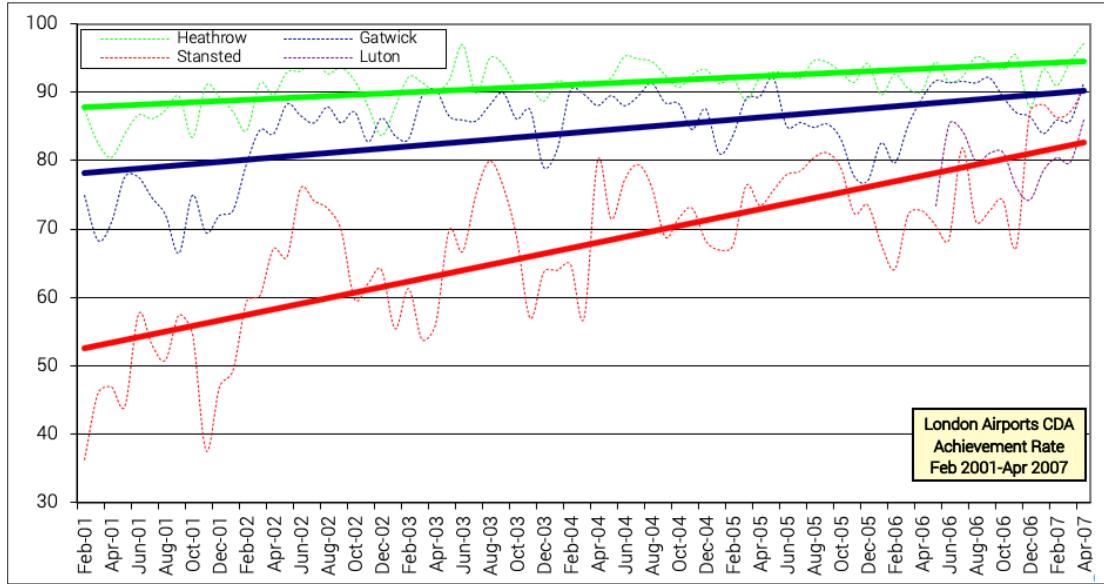


Figure 98: CDO performance improvement from 2001 to 2007 at the four main London airports

Once published, a review was conducted which concluded that CDAs were not an overnight phenomenon. ATCOs received training material on CDA while CDO performance feedback was also provided to Controllers with open Monthly Performance Reporting back to the watches.

November	Total Arrivals	CDA Approach	%
<b>Red</b>	114	109	95.61%
<b>Blue</b>	110	106	96.36%
<b>Green</b>	125	118	<b>94.40%</b>
<b>White</b>	113	106	<b>93.81%</b>
<b>Amber</b>	113	99	<b>87.61%</b>
<b>Total</b>	575	538	<b>93.57%</b>

Table 16: Example of NATS ATCO Watch CDO performance measurement statistics

Feedback was also given to the airlines, through the Airport Flight Evaluation Units to highlight poor compliance. Naming and shaming of poor performance did lead to inter-airline competition.

Controllers needing re-education, as did the Flight Crews. The idea was that a change in flying style was needed together with a review of SOPs by the airlines.

Following the success of the 2002 Arrivals Code of Practice, the working group was reformed to review the first version of the code and consider writing a second version. Version 2 was published in November 2006, again in Full and Abbreviated

versions. This publication updated current practices in use at the time and had a large number of participants. This version was again written for the three London Airports providing broad base guidelines on CDA.

In the intervening years between the two versions of the code being published, a group was established in the UK called Sustainable Aviation (SA), and in this group, an outreach programme was formed for CDAs and a further guide to Continuous Descent Operations published.

The progress demonstrated by the London airports was aided by the 2002 publication of the Arrivals Code of Practice and subsequent close monitoring and reporting of CDO. Prior to 2016, NATS has made savings of 6,176 tonnes of aviation fuel through improved Continuous Descents across the 14 airports where NATS provides the control service, equating to 19,600 tonnes of CO2 emissions saved. This is worth around £2.3M in savings for airlines. In 2016, this figure had risen again, saving airlines up to £6.5M.

During the CDO campaign, positive results were delivered, thanks to the improvement of CDO performance at UK airports.

- SA CDO airports: 4.8% increase in flights resulting in 32,070 more flights flying a CDA when compared to 2015. CDA compliance rate was 76.1%; and,
- SA CDO airlines: 3.4% increase in flights resulting in 13,023 more flights flying a CDA when compared to 2015. CDA compliance rate was 84.9%.

Overall, the Continuous Descent Campaign continues to improve descents across the UK, delivering over 810,632 individual quieter arrivals.

London CDA performance versus the UK average		
	(source airport NTK data)	(source NATS FMP data)
2000	66%	n/a
2006	84%	56%
2013	90%	74%
2015	89%	77%
2016	90%	76%

Table 17: London CDA performance versus the UK average

NATS, Airlines and Airports are working together to demonstrate joint industry action to tackle noise and reduce emissions.

### Performance Measurement: London Case Study – The Airport perspective

It is fully recognised that airports have a key role to play in driving CCO / CDO performance at lower altitudes. Through positive engagement with airlines, an ANSP's performance can be enhanced when all stakeholders are aware of requirements and current performance levels.

Heathrow Airport operates in some of the most constrained airspace in the world and faces some unique challenges in being able to deliver CCO / CDO performance. CDO is monitored from 6,000ft in part due to four holding stacks located in all four corners of the London Control Area (CTA).

Despite these challenges, Heathrow has seen an increase in CDO performance after implementing a quarterly league table that ranks the top 50 airlines (based on movements) according to their green credentials. This is known as the "Fly Quiet and

Green League Table" (FQG). While Heathrow provides financial incentives for airlines to use the quietest aircraft through variable landing charges, the FQG league table also provides airlines opportunities that can help them identify their strengths and weaknesses or highlight areas they can target for improvements to the KPIs in the programme, <https://www.heathrow-flyquietandgreen.com/>.

Airlines are ranked according to the following seven metrics:

1. Noise Quota / seat;
2. Chapter Number (ICAO Noise Certification);
3. NOx Emissions / seat;
4. CAEP standard (ICAO engine emissions certification);
- 5. Continuous Descent Approach (CDA) violations;**
6. Track Keeping violations; and,
7. Early or late movements between 23:30 and 04:30 local time.

It is fully recognised that some of these metrics are not easy to improve on. For example, metrics 1-4 can only be improved via a fleet mix change so are long-term strategic metrics. Metrics 5-7 are operational metrics and can easily be improved by altering the way the aircraft is flown. It is within an airline's power to improve these areas and as such, the final scoring for these metrics carries a higher weighting on the overall score so there is more incentive for performance improvement.

The league table is made public and attracts worldwide media attention. In consequence, Heathrow has seen a marked change in airline engagement. It is not always easy to engage with some airlines, but the league table has allowed the airport to open communication channels with all featured airlines. Being high up in the rankings is now considered as being "best in class," and promotes friendly competition with other airlines.

An example of improved FQG performance can be seen below. The graph represents the performance of a Middle Eastern long-haul airline which had an opportunity to improve their CDO performance. Heathrow began to engage with the airline in 2017 and, by providing regular feedback and help, saw the airline climb 40 places in the league table after seeing 98.4% of their arrivals comply with the CDO metric.

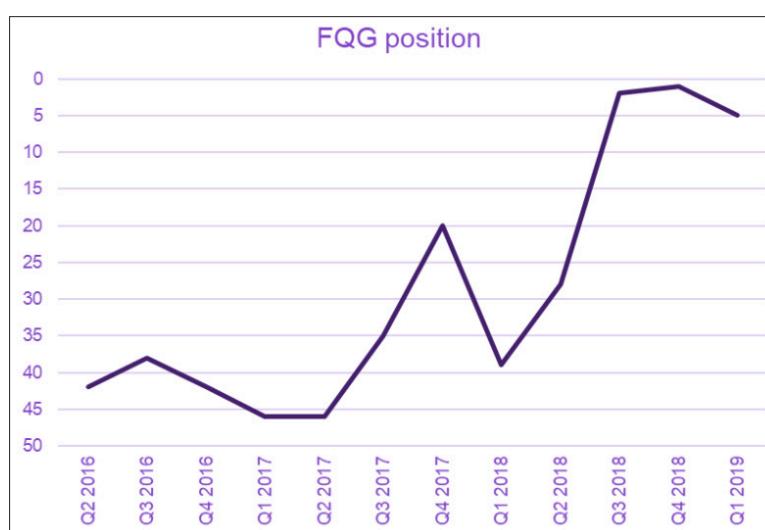


Figure 99: CDO performance improvement for a single airline following performance feedback and support for improvement

This airline was featured in their local media firstly for being a poor performer according to the metrics, and afterwards, for appearing in the top three. Heathrow also saw much more engagement from the airline CEO and this demonstrated that airlines wish to be perceived as having sound environmental credentials.

For those airlines who do not feature in the Fly Quiet League table owing to a smaller number of movements, Heathrow has introduced "Minimum Performance Standards." This lays out a minimum compliance threshold for four metrics. Similar to the FQG league table, it is a measure to promote engagement between the airport and airline. Unlike FQG, the results of the minimum performance standards are not publicised.

The four metrics are as below:

- CDA Compliance
- Track Keeping
- Noise Infringements
- 4% Climb Gradient Adherence

As part of this scheme, all the featured airlines have access to a website where they can review their own performance. This online portal, known as 'PerformTrak', allows them to view the flight tracks of any infringements; data is available 20 minutes after the flight has arrived / departed. This allows the airline to contact the crew almost immediately and to ascertain the reasons for infringements while the flight is still fresh in their minds.

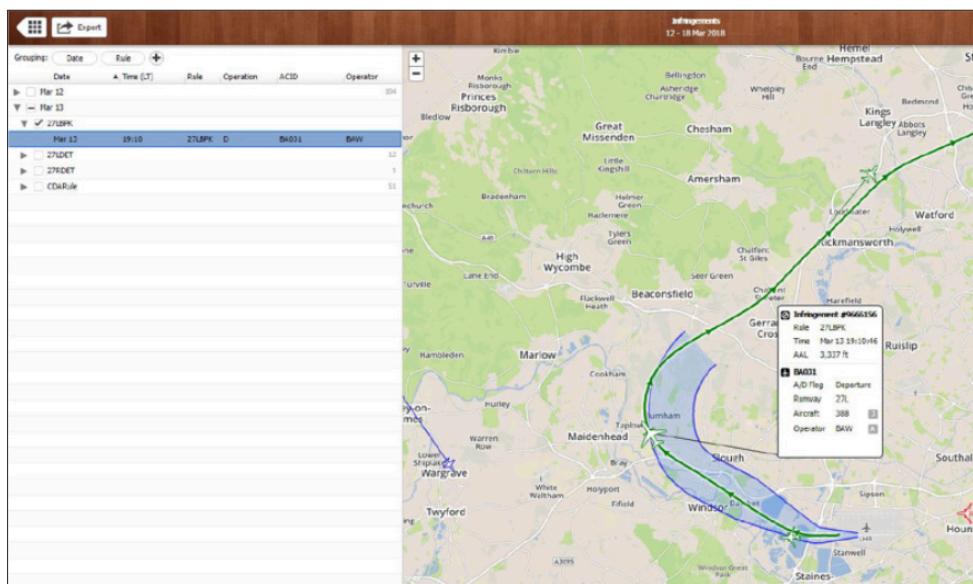


Figure 100: The UK PerformTrak Portal allowing airlines to review their own CDO performance

It should be good practice for any airport to regularly monitor CDA achievement rates and report on other performance metrics designed to make the airport more socially responsible. The idea of performance reporting is to encourage a joint industry approach to improving CDA performance. Both Fly Quiet and Green and Minimum Performance Standards show that through effective engagement, performance can be substantially improved.

## Performance Measurement: London Case Study - The Airline perspective

In the Airline survey on CCO / CDO conducted by the European CCO / CDO Task Force, it was seen that fewer than 35% of airlines which participated in the survey measure their CCO / CDO performance.

The study also revealed that more than 40% of airlines received CCO / CDO performance statistics from an airport source, namely London Heathrow, which is one of the only airports to share such statistics. **This means that one single airport provides CCO / CDO performance information to more airlines than the number of airlines that monitor their own performance. Clearly, Heathrow's airline performance tables are a vital source of performance material.**

If airlines were to receive similar performance data from other airports and more fuel CDO performance information for CDO from ToD, this would really help tell airlines where good performance exists and what it looks like.

This is the reason that the European CCO / CDO Task Force is developing CCO / CDO performance dashboard for all airports in Europe and all airlines that fly in Europe<sup>49</sup>. These tables should provide performance information to be shared with those stakeholders who do not currently have access to such data. They should allow all stakeholders to identify airports with poor CCO / CDO performance. Airlines whose own performance can be improved, should be notified and all stakeholders should work collaboratively to improve the performance of vertical flight efficiency for the climb and descent profiles.

In addition, although ANSPs and airlines are seen as the two vital elements in a CDO implementation, it can be seen that airports also have an important role to play: they can bring all stakeholders to the table, communicate performance statistics and maintain close links with the airlines by giving performance feedback and working collaboratively on improving performance.

### Performance Measurement: London Case Study – Conclusions

NATS and London Heathrow in particular have demonstrated that CDO performance measurement, be it on an airport, airline or individual ATCO Watch level, is a major enabler of CDO performance improvement. When practitioners know that their performance is being measured and results shared amongst their peers or disseminated publicly, it greatly facilitates performance improvement. This is known as the Hawthorne Effect: individuals modify their behaviour when they know that they are being observed.

CDO measurement in the UK focuses primarily on the noise CCO and noise CDO performance measurement i.e. those parts of the climb and descent profiles where noise is the primary environmental impact. CCO and CDO are measured in the UK using a binary indicator although the European CCO / CDO Task Force finds that the optimal performance indicator for measuring CCO / CDO is the “average time in level flight” as this indicator is able to pinpoint more granular performance changes.

However, regardless of the indicator used, the **mutual collaboration** by ANSPs, airlines and airports, performance monitoring and stakeholder feedback, together with the **follow-up engagement** between airport and airlines, may be considered essential ingredients in successful CCO / CDO implementation.

## Q5: Collaboration – “The Observatory” in Spain

Appendix Q2 details the essential need for focused and continuous ATCO / Flight Crew collaboration, cooperation and coordination in the design, development, assessment, trialing and implementation of new ATM and CDO procedures.

This case study highlights a collaborative study in Spain; the objective of this shared exercise was to educate Pilots / ATCOs on safety issues, environmental constraints and mitigations, and to come up with unique solutions for optimising the airspace.

This kind of collaborative exercise not only fills the gap between identifying the need for airspace and procedure optimisation and solution proposals, but also offers a unique opportunity to build the necessary trust and collaboration required between Pilots and ATC to obtain the critical buy-in for future airspace change proposals.

### Observatory of safety and efficiency of air operations of ENAIRE and COPAC

Maintaining safe and efficient air transport depends on coordination and close collaboration among the different parties involved in operations. In Spain, ENAIRE (the ANSP) and COPAC (the Pilot Union) have a shared objective: provide and guarantee air transport users a safe service of the highest quality. This being the case, on 8th May 2017, both parties signed a General Protocol of Action to establish a framework for collaboration on various issues related to the efficiency and improvement of air transport. On 2nd July 2019, an agreement was signed for the creation of the ‘Observatory of Safety and Efficiency of Air Operations’. This agreement has an initial duration of one year, extendable for three more years.

ENAIRE exercises competences in air navigation and airspace. It coordinates national and international operations in Spain's national air traffic management network and focuses on the efficient use of airspace.

The agreement with COPAC and the actions that derive from it are aligned with ENAIRE's functions in providing safe, efficient, high-quality and sustainable air traffic services.

On the other hand, the Official College of Commercial Aviation Pilots (COPAC) is a public corporation covered by Spanish Law and recognised by the State. COPAC's essential functions are to collaborate with the Administration in conducting studies, issuing of reports and preparing statistics as well as to carry out other activities on request.

In the 2019 agreement, it was established that the Observatory's activities would focus on:

- a) Improving mutual knowledge of the Pilots' and Controllers' operations;
- b) Identifying good practices to enhance safety and operational efficiency; and,
- c) Promoting an image of collaboration and transparency in an innovative project.

The Observatory's objective is to obtain data samples related to the safety and efficiency of real air operations, from specially trained COPAC Pilots and ENAIRE ATCOs.

After coming off duty, Observers have to fill out a form in which they identify any threats, errors or situations that affected the safety and efficiency of the air operations that they have observed during their work. These records have to be made without prejudice to the obligations regarding the notification of events and the processes of the respective Safety Management Systems, both of ENAIRE and of the airlines affected.

The information on these forms will be analysed by technical experts, who will prepare reports on the trends observed and assess how the various situations were being managed.

These reports will subsequently be reviewed in formal working groups (technical event review groups), constituted by the

observers themselves, together with a coordinator. They will try to identify improvement actions, as well as strengths and good practices. If relevant safety issues are detected, these have to be brought to the attention of the respective Safety Management Systems of ENAIRE and the airlines in question.

Once the conclusions of the observations and the technical groups have been obtained, data will be published on the Observatory website and information sessions will be held for Pilots and ATCOs.

## **Actual situation**

COPAC selected the Pilot Observers from its members. The sample of the selected Pilot observers was formed by Flight Crews that operate into the five main airports of Spain: Madrid, Barcelona, Palma de Mallorca, Malaga and Gran Canaria, in a ratio proportional to the airlines and type of aircraft flying in Spain. For this, it was initially estimated that 37 Pilots were required.

The airlines of these Pilots were fully aware of their participation in the Observatory and accepted their participation through the signing of a Confidentiality Agreement, which protects the data provided and the identity of the Pilots.

ENAIRE is in the process of selecting ATCO Observers from amongst its staff. The sample of Controllers will be made up of ATCOs belonging to the ACCs and towers of the five main airports, which provide aerodrome, approach and area air traffic control services. Initially, it was estimated that around 30 Controllers would be needed.

Both the size and composition of both samples of Pilots or ATCOs may be adjusted by prior agreement between COPAC and ENAIRE according to the evolution of traffic, so that it is representative of air operations in Spain, and the needs that arise from the activities of the Observatory.

COPAC and ENAIRE have jointly agreed on the content of the data collection forms by both the Pilot Observers and Air Traffic Control Observers. These forms are in the draft phase and are currently being modified with contributions from the Observers. Proposals for adaptation to standardised measurement criteria, in which EUROCONTROL's support is considered important, will ensure that the measurements are will be in line with current harmonised practices.

Once the content has been agreed upon, COPAC will manage the contracting of the development of the "Qliksense" data collection application, to which the forms will be transferred in order to facilitate the collection of data by the observers.

## **Training of the observers**

Both COPAC and ENAIRE are responsible for providing adequate training for all personnel carrying out their activities in the Observatory. The differences between their functions are clearly aligned with the requirements set forth in Regulation (EU) 376/2014 of the European Parliament and of the Council, published on 3rd April 2014, concerning the notification of events in civil aviation.

In order to ensure that data capture is carried out in a standardised manner by all observers, prior to the start of data capture, face-to-face training sessions have been carried out in the five ACCs, for both Pilots and Controllers.

The duration of each training activity has been two days and has included practical cases of filling in questionnaires.

COPAC is in charge of the hiring of the training design, the preparation of the material and the remuneration of the trainers. Observation of the Operations

Observations will be made annually of at least one per thousand of the total flights made in the five terminal areas chosen. During the flight or the control shift, the observers will pay special attention to the identification of practices, situations or behaviours that have facilitated or hindered the efficiency of the flight, as well as threats, unwanted situations, good practices and practices to avoid in relation to safety. These practices, situations or behaviours will include the application and implementation of CDO.

The data capture will always be undertaken at the end of the flight and the control shift, by completing a de-personalised questionnaire developed in the Qliksense mobile application.

## **Data Analysis**

Data captured in the mobile application will be analysed by technical experts (hired by COPAC) who will prepare monthly reports on flight safety and efficiency. In carrying out the analysis, the analysts will have these tools, the contracting for which being managed by COPAC:

- Qliksense: it will provide statistics on the efficiency of the operations observed: consumption, flight times, etc.; and,
- Bowtie: the analysts will make representations of the day-to-day operational processes, documenting, integrating and quantifying the level of exposure to existing threats, the effectiveness of the barriers or control mechanisms and aggravating factors or consequences.

## **Good practices identification**

The reports prepared by the analysts will be reviewed quarterly by the Technical Event Review Groups, constituted by the observers themselves, in which they will try to identify improvement actions, as well as strengths and good practices. In order to carry out exhaustive analyses and facilitate the identification of concrete improvement actions, there will be a technical group in each control centre.

From each meeting, the Coordinator will prepare a summary that includes the topics discussed, the conclusions reached and the actions to be taken. From these minutes, the analysts will prepare quarterly executive reports.

In the case of identifying relevant safety issues, these will be brought to the attention of the respective Safety Management Systems, of both ENAIRE and the affected airlines.

## Disclosure of results

As results and conclusions derived from the Observatory are obtained, various disclosure activities will be carried out to the different interest groups:

### OBSERVATORY – DISCLOSURE OF RESULTS

- a. Creation of the Observatory Portal: in which the results of the indicators will be published, together with news derived from the Observatory. It will consist of a public area with global and airport results and an area for registered professionals, in which the indicators will reach higher levels of detail. COPAC will manage the contracting of the Portal development;
- b. Holding information sessions for professionals: information sessions will be held semi-annually in the five large airports or in the control centres, aimed at Pilots and Controllers. ENAIRE will provide a room suitable for the number of attendees and with the necessary means to provide the information and for the recording of the event, if deemed appropriate;
- c. Edition of Controller / Pilot videos: short Controller / Pilot videos will be prepared with a summary of the conclusions and good practices resulting from the information sessions;
- d. Dissemination through social networks: both the positive achievements and the activities of the Observatory.

## Management of the Observatory

In order for the Observatory to function properly, COPAC provides a full-time Coordinator and an Observatory Manager.

The Observatory Coordinator is responsible for planning and coordinating activities related to observations and data analysis (observer training planning, planning and observation requirements, technical contact with software vendors, supervision of data analysts, coordination of technical event review groups, etc.).

The Observatory Manager is responsible for administering the Observatory's resources (constitution of the observer team, contracting and software development, etc.) as well as the quality control of the activities (review of the reports made by the analysts, of the minutes of the technical event review groups, etc.). The Observatory Manager is also responsible for coordinating the Observatory's communication and promoting different tasks.

The Manager is supported by a part-time Legal Technician, hired by COPAC, and by other professionals in various fields, from both COPAC (economic-financial, communication, etc.) and ENAIRE (quality, security, communication, etc.).

The Manager reports to the Governing Committee on the performance and results of the Observatory, of which it will be a part, to support the conclusions obtained and the actions derived from them.

In order to carry out all the activities of the Observatory, the signed agreement has associated economic clauses on the contribution of resources by both entities.

## Q6: Performance monitoring from the Airline perspective - Wizz Air

Airlines can use aircraft-derived data for CDO monitoring and data can be presented in a myriad of different ways. One such example from Wizz Air illustrates how this airline benchmarks CDO performance by individual flights / Pilots. The performance statistics are given to the Pilots; they show each individual what their performance is like, and more importantly, where it is ranked, compared to the performance of all other Flight Crew at the same base.

As an airline with a fleet of 120+ aircraft, consisting solely of Airbus A320 / A321 (ceo / neo), Wizz Air wanted to systemise the performance of its flights after a thorough QAR data analysis revealed that there were major differences in the average descent fuel consumption across Pilots operating from the same crew base.

The magnitude of the differences was high enough to place descent optimisation into Wizz Air's TOP 5 initiatives for CO2 reduction. A detailed data analysis of the QAR data revealed that the airline's performance was particularly weak in areas such as:

- Delaying the ToD which resulted in high speed descents;
- Deceleration and configuring early for approach;
- Non-efficient use of aircraft automation and the FMS;
- Inaccurate calculations of the FMS; and,
- Inappropriate design of the arrival procedures resulting in the inability to take advantage of the FMS calculations.

Wizz Air worked with Storkjet and the Silesian University of Technology to identify fuel burn inefficiencies using QAR data as the source of fuel burn data. The analysis concluded that the precision of key performance model output parameters (i.e. fuel flow) creates the foundation for high-precision integrated models and accurate outputs see Figure 101.

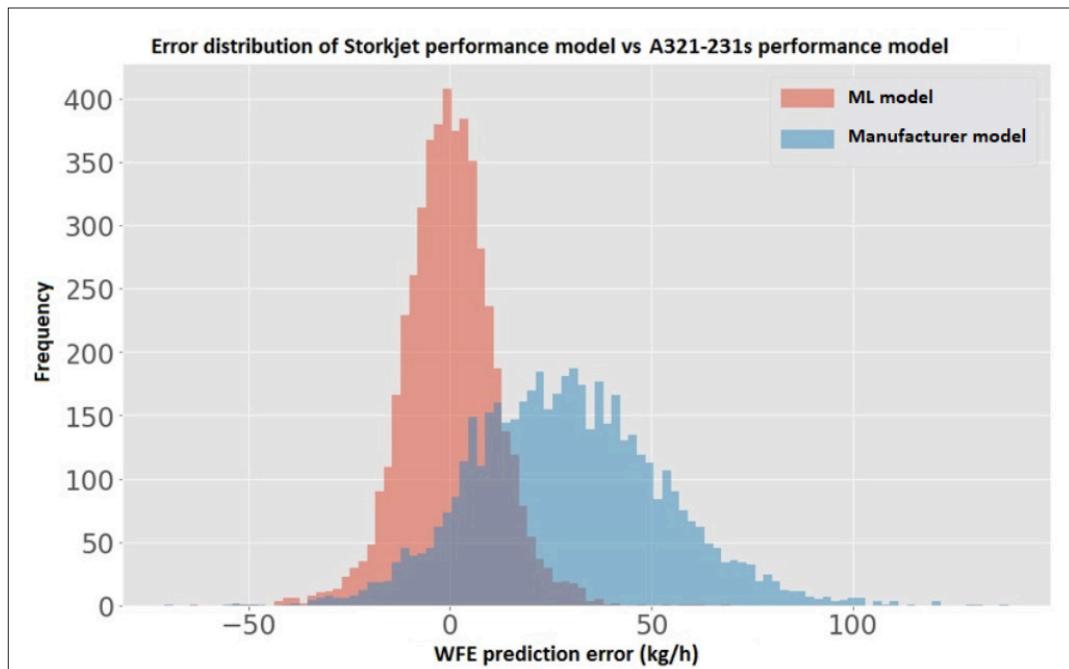
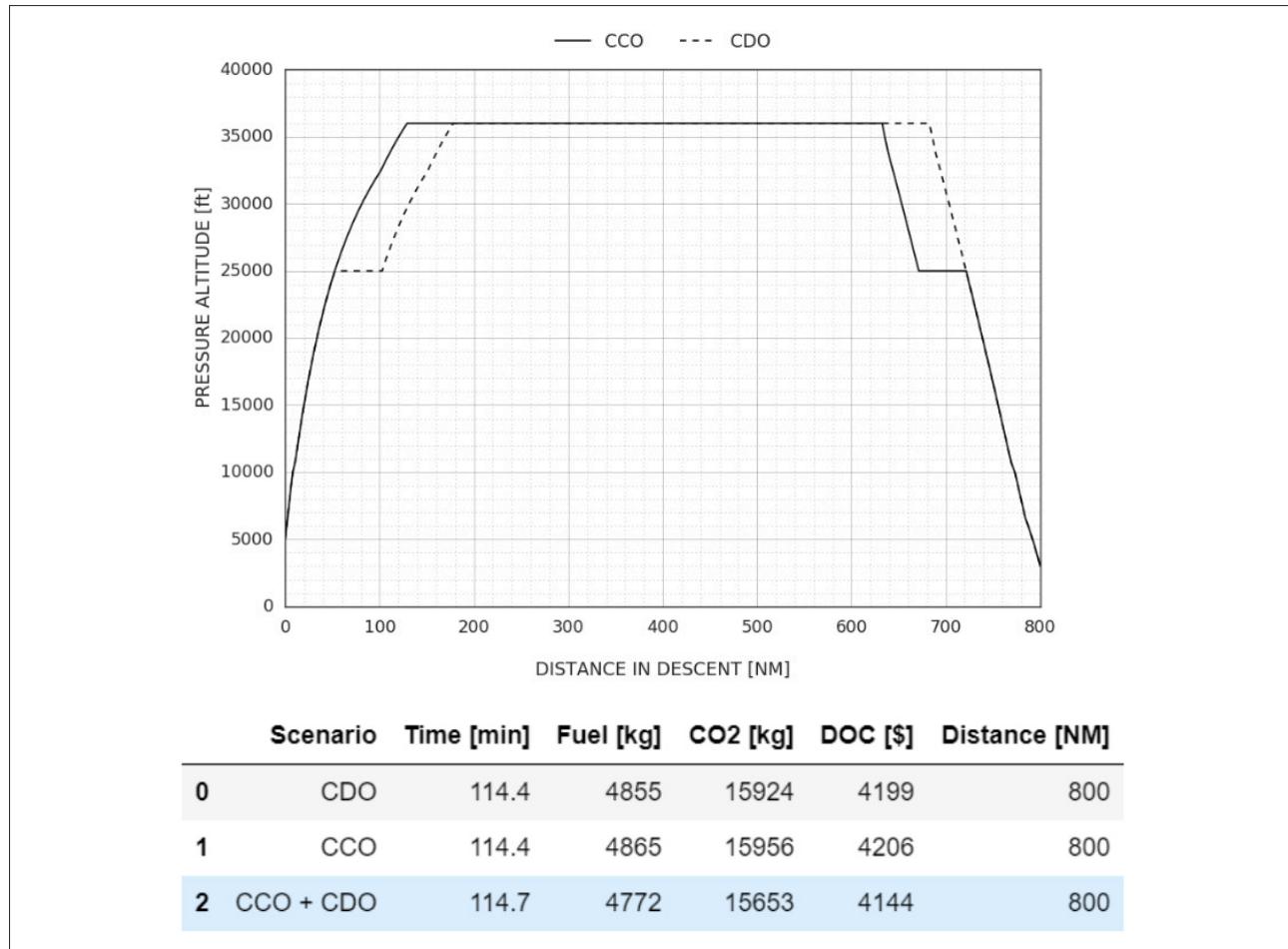


Figure 101: Error distribution of Storkjet performance model in Wizz Air analysis

The conclusions of the analysis agreed with the recommendations of the Action Plan, namely that not only were higher level-off segments more efficient than lower segments, but a CDO (plus a step climb) saved more fuel than a CCO (plus a step descent at the same level).

This means that if there was a choice between a 50nm level-off at FL250 in the climb phase OR the descent phase, the level-off in the climb phase would generate more fuel savings: see Figure 102. The root cause of this conclusion was the fuel burn difference between step-level altitude and the optimum altitude – this difference was much smaller in the climb.



**Figure 102: A comparison of fuel burn for a Wizz Air A321 comparing a CDO (+ step climb) versus a CCO (+ step descent) with the same length of level segment and FL in climb and descent**

The data availability and accuracy of fuel burn performance modelling prompted Wizz Air to carry out a benchmarking exercise on the fuel burn performance of the descent phase of flight. The objectives of this benchmarking performance were to reduce the total descent fuel consumption from a pre-defined distance from touchdown until the final approach. This distance was agreed on the basis that it should be as short as possible, but far enough to include the part of the cruise component i.e. capture the ToD and enable a comparison between airport arrival performance. The nominal distance was set at 150nm.

The performance measurement programme was developed internally with collaboration between the Flight Operations and the Information Technology Departments, with QAR output as the principal data source together with additional information provided by Flight Crew.

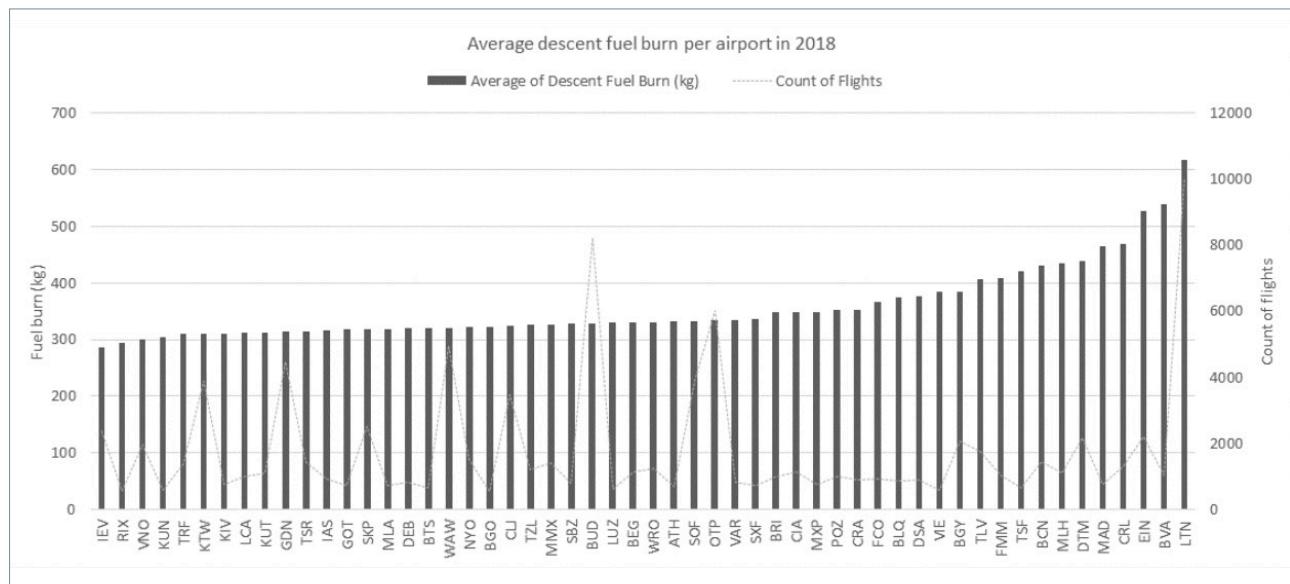
The primary KPI developed was the 'total fuel consumption during descent'. The Wizz Air QAR data is made available once a flight has landed and the QAR is connected to the local 4G network, downloading all kinds of performance data that can be used not only for fuel burn performance analyses but also for safety analyses and other regulatory requirements.

As the QAR data was available, Wizz Air considered the identified metric was more appropriate and accurate, given the data availability as it would give immediate fuel burn data as opposed to using the proxy of level flight segments.

The total fuel consumption during descent was measured for each airport where Wizz Air had a base with feedback on performance given to all Pilots at each base every month. The feedback included the analysis of all fuel efficiency-related initiatives, including descent performance feedback and included the number of sectors flown per Pilot.

The performance feedback allows each individual Pilot to see their own descent efficiency score and more, importantly, where they rank amongst all other Pilots at the base. Each individual is able to see only their own performance whereas the fuel efficiency manager is able to identify each Pilot. This allows the airline to support individual Pilots with refresher training or to follow up on the reasons for a certain performance level, but **it is not a punitive culture** – there are no performance bonuses for better than average performance and there are no penalties for lower than average performance. The analysis may be compared with a number of human characteristics e.g. age, Pilot background (e.g. military / civil / business aviation) etc. which can identify where Flight Crew CDO training could be more focused.

When average performances per base are compared, Wizz Air is able to identify straight away which airports have more constraints or inefficiencies in the descent profile. It can adopt a pro-active approach to working with individual airports with the aim of further optimising CDO – yet another benefit of performance monitoring.



**Figure 103: Comparison of fuel burn consumption per airport in 2018 for 50 most popular Wizz Air bases.**  
Fuel burn is defined as fuel burned from 120nm until 5nm before landing.

Figure 103 shows the amount of average fuel burn per arrival from 120nm to 5nm to touchdown at the 50 biggest bases.

This figure highlights the reference fuel that is required at the more efficient airports and could be used as a benchmark for measuring the additional fuel burned at less efficient airports; at times it may even be double the amount of reference fuel burn.

In the first year of descent fuel burn monitoring, the total descent fuel consumption was reduced by 8%. This was achieved primarily by higher compliance with ECON speed on descent and a more accurate estimation of the ToD.

It should be noted that descent performance was reported only for descent to unrestricted airports. "Unrestricted" means that there are no complex arrival procedures and arriving traffic is low, so allowing full control over the descent profile. Such airports constitute 50% of Wizz Air's network – so in reality, the 8% fuel savings were generated by only half of the flights that Wizz Air operates.

One example of a significant improvement in descent fuel burn can be demonstrated at Oslo Torp airport. Figure 104 shows the descent fuel burn data after the introduction of modified descent procedures with an emphasis on the importance of accurate ToD point estimation in January 2018. The six-month moving average fuel burn values clearly demonstrate double-digit performance improvement in the first 12 months, together with a clear indication of the cyclical nature of CDO performance: in winter CDO performance is affected more by weather and in summer more by traffic intensity.

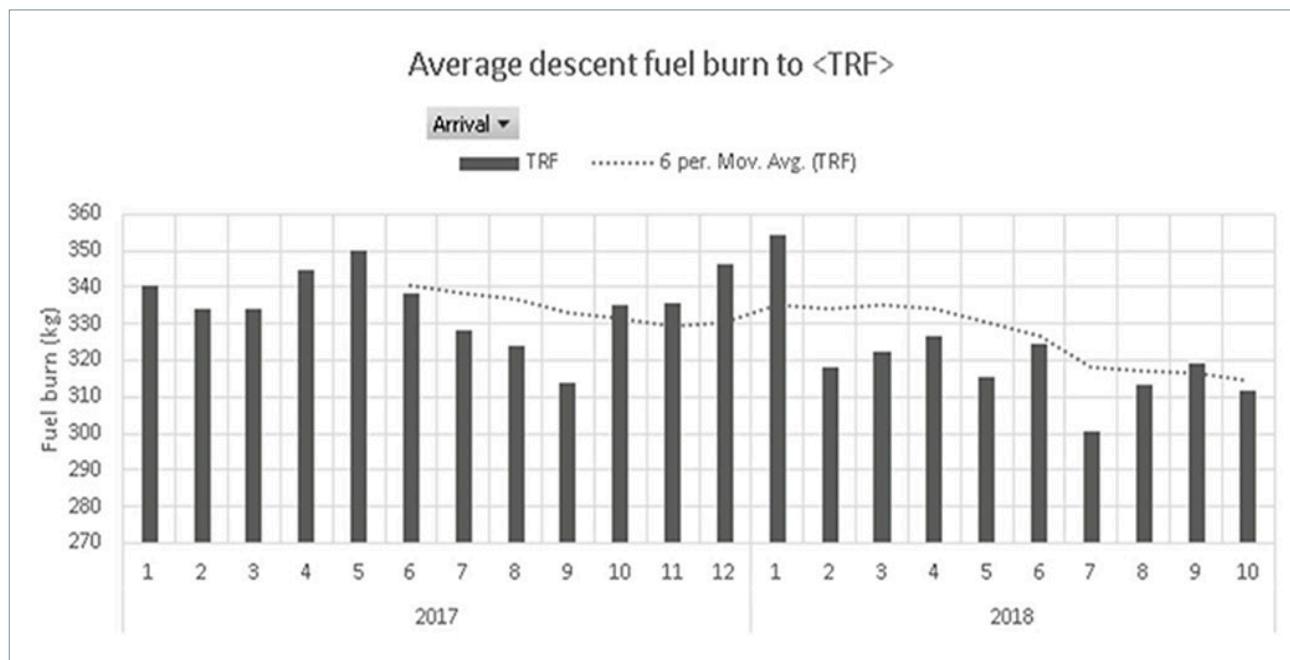


Figure 104: Change in average descent fuel burn at Oslo Torp (TRF) airport

Based on the success of this initiative, Wizz Air have taken the main outcomes of the fuel benchmarking study and created training materials for descent management that have been developed in collaboration between the Flight Operations and Training departments.

Following the observed improvement in descent performance, Wizz Air have also identified further potential fuel savings using QAR data such as:

- Improvement of FMS calculations, consideration is being given to furnishing the FMS with Descent Profile Optimisation modifications;
- Application of accurate IDLE factors which help the FMS to determine optimum descent more accurately; and,
- Enabling automatic wind-uplink data to FMS before the aircraft starts the descent.

Should these steps prove successful, the Wizz Air fuel efficiency team will recommend updates to operating procedures in the OM in order to maximise the advantages of automation.

One final indication of the benefits of measuring CDO performance using QAR data can be seen in Figure 105. The optimum fuel burn usage in a 120nm to 5nm descent may be in the range of 260kg fuel. This picture shows an example of descent "Actual" where ATC enabled unconstrained descent and the Flight Crew almost totally adhered to the recommended practices. If you compare these values with the values of the best performing airports in Figure 103 - Kiev (IEV) and Riga (RIX) - you will see at those airports, approximately 30kg of fuel burn from a perfect idle profile is achieved. This means that these airports create very good conditions for Flight Crews to perform green, idle descents. However, the remaining 30-40kg of possible fuel savings can only be made by better piloting techniques.

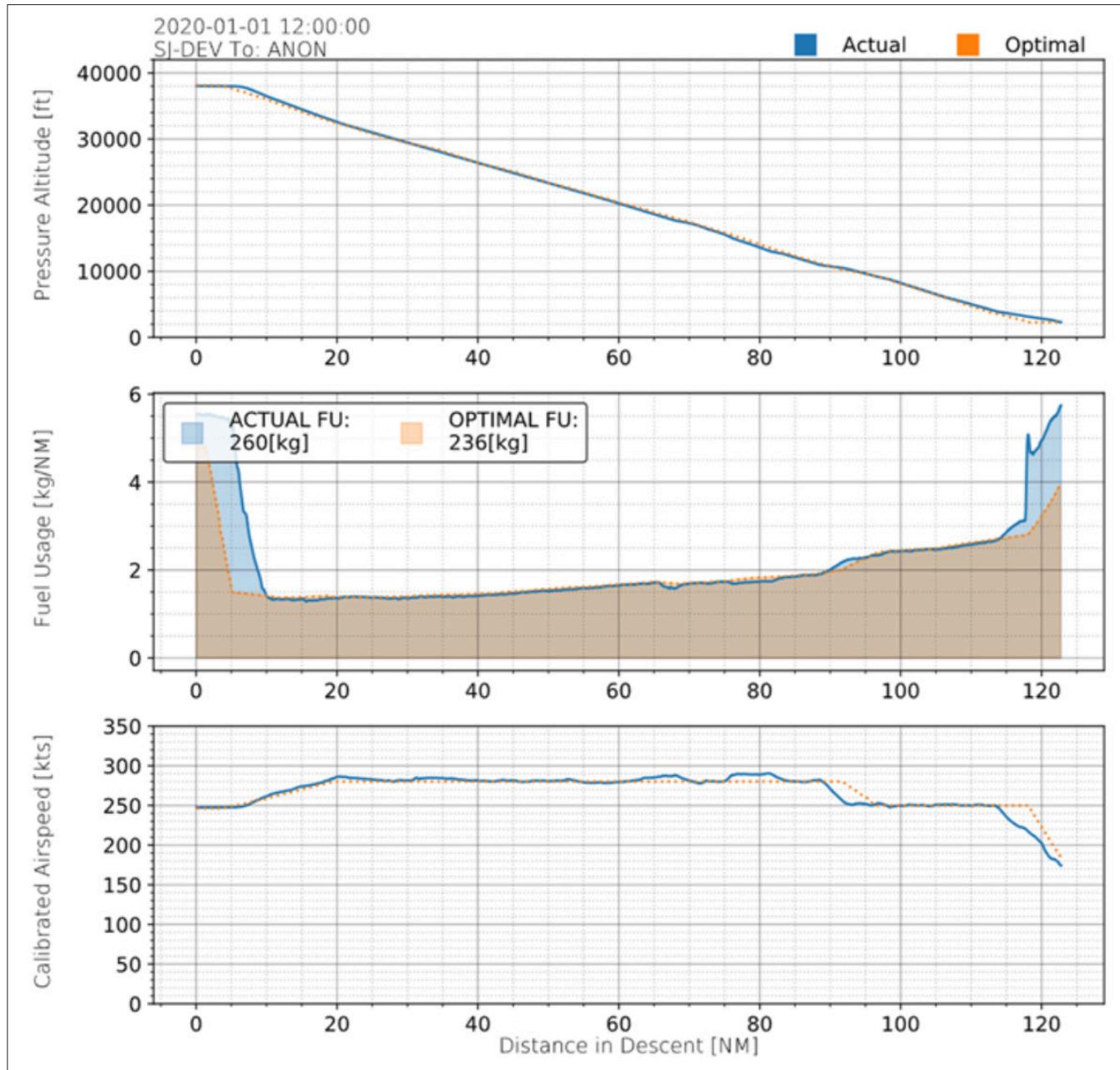


Figure 105: detailed fuel burn analysis of a 'perfect' descent



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