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AN/476



Continuous Descent Operations (CDO) Manual

Approved by the Secretary General
and published under his authority

First Edition — 2010

International Civil Aviation Organization

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FOREWORD

The purpose of this manual is to provide guidance on continuous descent operations (CDO) and to harmonize its development and implementation. To achieve this, airspace design, instrument flight procedure design and air traffic control (ATC) techniques should all be employed in a cohesive manner. This will then facilitate the ability of flight crews to use in-flight techniques to reduce the overall environmental footprint and increase the efficiency of aircraft operations.

Note.— The generic term “continuous descent operations” has been adopted to embrace the different techniques being applied to maximize operational efficiency while still addressing local airspace requirements and constraints. These operations have been variously known as continuous descent arrivals, continuous descent approaches, optimized profile descent, tailored arrivals and 3D/4D path arrival management forming part of the business trajectory concept.

The implementation guidance in this manual is intended to support collaboration among the following stakeholders involved in implementing continuous descent operations:

- a) air navigation service providers (ANSP), including:
 - 1) policy/decision makers;
 - 2) airspace designers;
 - 3) procedure designers; and
 - 4) operational ATC staff;
- b) aircraft operators:
 - 1) policy/decision makers;
 - 2) senior pilots; and
 - 3) technical (FMS expertise) staff;
- c) airport operators including:
 - 1) operations department; and
 - 2) environment department;
- d) aviation regulators.

Future developments

Comments on this manual would be appreciated from all parties involved in the development and implementation of CDO. These comments should be addressed to:

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EXECUTIVE SUMMARY

This manual contains guidance material on the airspace design, instrument flight procedures, ATC facilitation and flight techniques necessary to enable continuous descent profiles. It therefore provides background and implementation guidance for:

- a) air navigation service providers;
- b) aircraft operators;
- c) airport operators; and
- d) aviation regulators.

The key objectives of this manual are to improve the:

- a) overall management of traffic and airspace in order to enable uninterrupted continuous descents, without disrupting departures;
- b) understanding of continuous descent profiles; and
- c) understanding and harmonization of associated terminology.

CDO is one of several tools available to aircraft operators and ANSPs to increase safety, flight predictability and airspace capacity, while reducing noise, fuel burn, emissions and controller-pilot communications. Over the years, different route models have been developed to facilitate CDO, and several attempts have been made to strike a balance between ideal fuel-efficient and environmentally friendly procedures and the capacity requirements of a specific airport or airspace.

It is expected that future developments will allow different means of realizing the performance potential of CDO without compromising the optimal airport arrival rate (AAR). The core CDO concept at the heart of this manual will also apply to increasingly sophisticated methods of facilitating CDO.

CDO is enabled by airspace design, procedure design and facilitation 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 the top-of-descent (TOD) and uses descent profiles that reduce controller-pilot communications and segments of level flight. Furthermore it provides for a reduction in noise, fuel burn and emissions, while increasing flight stability and the predictability of flight path to both controllers and pilots.

The standardization of procedures is important for flight safety and needs to be designed and presented in an unambiguous manner. For the procedure designer, it is important to understand the flight characteristics, limitations and capabilities of aircraft expected to perform CDO, as well as the characteristics of the airspace and routes where it will be used. For airport operators and environmental entities, it is important to understand the extent and limitations of environmental benefits, aircraft performance and airspace limitations when proposing to introduce CDO. Considering the high cost of fuel and growing concerns about the environment and climate change, collaborating to facilitate CDO is an operational imperative for all stakeholders.

It is of paramount importance that safety be maintained during all phases of flight — nothing in this guidance shall take precedence over the requirement for the safe operation and control of aircraft at all times. To avoid doubt, all recommendations are to be read as being “subject to the requirements of safety”.

Before any CDO trials or operations commence, the proposed implementation needs to be the subject of a local safety assessment.

REFERENCES

Note.— Documents referenced in this manual or affected by continuous descent operations.

ICAO documents

Annex 4 — *Aeronautical Charts*

Annex 6 — *Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes*

Annex 6 — *Operation of Aircraft, Part II — International General Aviation — Aeroplanes*

Annex 8 — *Airworthiness of Aircraft*

Annex 10 — *Aeronautical Telecommunications, Volume I — Radio Navigation Aids*

Annex 11 — *Air Traffic Services*

Annex 15 — *Aeronautical Information Services*

Annex 17 — *Security — Safeguarding International Civil Aviation against Acts of Unlawful Interference*

Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM) (Doc 4444)

Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) (Doc 8168)

Volume I — *Flight Procedures*

Volume II — *Construction of Visual and Instrument Flight Procedures*

Regional Supplementary Procedures (Doc 7030)

Manual on Testing of Radio Navigation Aids (Doc 8071)

Air Traffic Services Planning Manual (Doc 9426)

Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689)

Global Navigation Satellite System (GNSS) Manual (Doc 9849)

Safety Management Manual (SMM) (Doc 9859)

European Organisation for Civil Aviation Equipment (EUROCAE) documents

Minimum Operational Performance Specifications for Airborne GPS Receiving Equipment used for Supplemental Means of Navigation (ED-72A)

MASPS Required Navigation Performance for Area Navigation (RNAV) (ED-75B)

Standards for Processing Aeronautical Data (ED-76)

Standards for Aeronautical Information (ED-77)

RTCA, Inc. documents

Standards for Processing Aeronautical Data (DO-200A)

Standards for Aeronautical Information (DO-201A)

Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment using the Global Positioning System (DO-208)

Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation (DO-236B)

Aeronautical Radio, Inc. (ARINC) 424 documents

ARINC 424-15 Navigation System Database Specification
ARINC 424-16 Navigation System Database Specification
ARINC 424-17 Navigation System Database Specification
ARINC 424-18 Navigation System Database Specification

ACRONYMS

AAR	Airport arrival rate
ADS-B	Automatic dependent surveillance — Broadcast
ANSP	Air navigation service provider
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic services
CDO	Continuous descent operations
CFIT	Controlled flight into terrain
CG	CDO collaborative implementation group
CIG	CDO implementation group
DTW	Downwind termination waypoint
EUROCAE	European Organisation for Civil Aviation Equipment
FAF/FAP	Final approach fix/final approach point
FM	Fix to manual termination
FMC	Flight management computer
FMS	Flight management system
IAF	Initial approach fix
ICAO	International Civil Aviation Organization
IF	Intermediate fix
ILS	Instrument landing system
LNAV	Lateral navigation
MSL	Mean sea level
NASA	National Aeronautics and Space Administration (United States)
NM	Nautical mile
OPD	Optimized profile descent
PBN	Performance-based navigation
PSR	Primary surveillance radar
RF	Radius to fix
RNAV	Area navigation
RNP	Required navigation performance
SID	Standard instrument departure
SSR	Secondary surveillance radar
STAR	Standard instrument arrival
TA	Transition altitude
TF	Track to fix
TL	Transition level
TOD	Top of descent
TOR	Terms of reference
VM	Heading to manual termination
VNAV	Vertical navigation

EXPLANATION OF TERMS

Approach procedure with vertical guidance (APV). An instrument approach procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.

Area navigation (RNAV). A method of navigation which permits aircraft operations on any desired flight path within the coverage of ground- or spaced-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Note.— Area navigation includes performance-based navigation as well as other operations that do not meet the definition of performance-based navigation.

ATS surveillance service. A term used to indicate a service provided directly by means of an ATS surveillance system.

ATS surveillance system. A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

Note. — A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.

Closed path CDO procedures. Procedures coded with track to fix (TF) legs and fly-by waypoints. STARs that terminate with a link to an instrument approach procedure should terminate at a fly-by waypoint. STARs that terminate with vector-based legs may be coded with fix to manual termination (FM) or heading to manual termination (VM) path terminators.

Continuous descent operation (CDO). An operation, enabled by airspace design, procedure design and ATC facilitation, 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.

Note 1.— An optimum CDO starts from the top of descent and uses descent profiles that reduce segments of level flight, noise, fuel burn, emissions and controller/pilot communications, while increasing predictability to pilots and controllers and flight stability.

Note 2.— A CDO initiated from the highest possible level in the enroute or arrival phases of flight will achieve the maximum reduction in fuel burn, noise and emissions.

Mixed navigation environment. An environment where different navigation specifications may be applied within the same airspace (e.g. RNP 10 routes and RNP 4 routes in the same airspace) or where operations using conventional navigation are allowed in the same airspace with RNAV or RNP applications.

Navigation aid (navaid) infrastructure. Space-based and/or ground-based navigation aids available to meet the requirements in the navigation specification.

Navigation application. The application of a navigation specification and the supporting navaid infrastructure, to routes, procedures, and/or defined airspace volume, in accordance with the intended airspace concept.

Note.— The navigation application is one element, along with communication, surveillance and ATM procedures which meet the strategic objectives in a defined airspace concept.

Navigation function. The detailed capability of the navigation system (such as the execution of leg transitions, parallel offset capabilities, holding patterns, navigation databases) required to meet the airspace concept.

Note.— Navigational functional requirements are one of the drivers for the selection of a particular navigation specification. Navigation functionalities (functional requirements) for each navigation specification can be found in the Performance-based Navigation (PBN) Manual (Doc 9613), Volume II, Parts B and C.

Navigation specification. A set of aircraft and flight crew requirements needed to support performance-based navigation operations within a defined airspace. There are two kinds of navigation specifications:

Required navigation performance (RNP) specification. A navigation specification based on area navigation that includes the requirement for performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

Area navigation (RNAV) specification. A navigation specification based on area navigation that does not include the requirement for performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

Note 1.— The Performance-based Navigation (PBN) Manual (Doc 9613), Volume II, contains detailed guidance on navigation specifications.

Note 2.— The term RNP, previously defined as “a statement of the navigation performance necessary for operation within a defined airspace”, has been removed (...) as the concept of RNP has been overtaken by the concept of PBN. The term RNP (...) is now solely used in the context of navigation specifications that require performance monitoring and alerting, e.g. RNP 4 refers to the aircraft and operating requirements, including a 4 NM lateral performance with on-board performance monitoring and alerting that are detailed in the PNB Manual (Doc 9613).

Open path CDO procedures. Procedures which require that after the DTW, an FM path terminator should be coded. In contrast, if ATC requires a defined path, a VM path terminator can be used instead.

Optimized profile descent (OPD). A descent profile normally associated with a published arrival (STAR) and designed to allow maximum practical use of a CDO. It starts from top of descent, taking into consideration the limitations of the local airport, airspace, environment, traffic and aircraft capabilities, and ATC. To the extent possible the descent profile is comprised of idle-power performance descent profile segments and geometric descent profile segments that maximize altitude, minimize the thrust required to remain on the path, terminate the path at the desired end location and satisfy the altitude and speed constraints along the closed path design.

Note.— OPD is one method of facilitating CDO.

Performance-based navigation (PBN). Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.

Note.— Performance requirements are expressed in navigation specifications (RNAV specification, RNP specification) in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

Procedural control. Term used to indicate that information derived from an ATS surveillance system is not required in the provision of air traffic control service.

RNAV operations. Aircraft operations using area navigation for RNAV applications.

RNAV system. A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. An RNAV system may be included as part of a flight management system (FMS).

RNP operations. Aircraft operations using an RNP system for RNP navigation applications.

RNP route. An ATS route established for the use of aircraft adhering to a prescribed RNP navigation specification.

RNP system. An area navigation system which supports on-board performance monitoring and alerting.

Standard instrument arrival (STAR). A designated instrument flight rule (IFR) arrival route linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commenced.

Standard instrument departure (SID). A designated IFR departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of a flight commences.

Part A

**CONTINUOUS DESCENT OPERATIONS
OVERVIEW**

Chapter 1

DESCRIPTION OF CONTINUOUS DESCENT OPERATIONS

1.1 INTRODUCTION

1.1.1 Continuous descent operations (CDO)

1.1.1.1 CDO is an aircraft operating technique aided by appropriate airspace and procedure design and appropriate ATC clearances enabling the execution of a flight profile optimized 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. ILS).

1.1.1.2 The optimum vertical path angle will vary depending on the type of aircraft, its actual weight, the wind, air temperature, atmospheric pressure, icing conditions and other dynamic considerations. A CDO can be flown with or without the support of a computer-generated vertical flight path (i.e. the vertical navigation (VNAV) function of the flight management system (FMS)) and with or without a fixed lateral path. However, the maximum benefit for an individual flight is achieved by keeping the aircraft as high as possible until it reaches the optimum descent point. This is most readily determined by the onboard FMS.

1.1.2 Facilitating continuous descent operations

1.1.2.1 Air traffic controllers are required to provide safe and efficient management of arriving aircraft. However, the term “efficiency” can mean different targets to different stakeholders and may vary depending on traffic density levels, aircraft mix or weather. To achieve overall arrival and departure efficiency, a balance should be struck between expediting traffic, meeting airport capacity, and reducing flight times, flight distances, fuel burn, emissions and noise within the overall requirement for safe operations. Environmental impact is a significant issue for aviation in general and should be considered both when designing airspace and instrument flight procedures, and when managing aircraft operations. Specifically, techniques that enable a fuel-efficient (minimum thrust) optimum descent and approach should be used wherever and whenever possible. The total energy of the aircraft at high altitude can be used most efficiently during descent with minimum thrust and drag. The pilot should however have the maximum flexibility to manage the aircraft’s speed and rate of descent.

1.1.2.2 Ideally, to maximize the benefit of a CDO it should start at the top of descent and continue through to the final approach fix (FAF)/final approach point (FAP) or establishment on the landing guidance system. Traffic sequencing could be achieved by small speed interventions during the cruise or early phases of descent, thereby minimizing sequencing manoeuvres at lower altitudes with the consequent benefit on fuel burn and noise. The level and speed windows of standard instrument arrivals (STARs) and approach procedures must be designed to take account of aircraft performance limits and be executed with a good knowledge of the wind data available to the pilot by manual entry or data link.

1.1.2.3 Such “3D” and in the longer term “4D” (with time control) CDO remains the ultimate goal for optimized profile descents. However, CDO carried out with appropriate ATC clearances and within the constraints of existing STAR or approach procedure designs, and over shorter sections of the descent, can provide significant benefits. One such example is where sequencing is achieved by path stretching, that is, the pilot when under vectoring is provided with information on distance-to-go, e.g., distance to the runway threshold. With this information available, the aircraft rate of descent can be adjusted in a more efficient manner. A mixture of this and other methods could also be applied.

1.1.2.4 The traffic density levels at which CDO can be routinely carried out may increase with the advent of controller tools such as arrival management tools and with the development of more sophisticated CDO designs. For optimum traffic handling in busy periods at high-capacity airports, air traffic controllers may need to use tactical intervention, i.e. vectoring and/or speed control, to sequence and separate aircraft. However, this need not prevent the continued application of CDO to provide the foundations of continual improvement. CDO facilitation methods should be selected and designed with the goal of allowing the highest percentage of use during the broadest periods of air traffic operations.

1.1.3 Benefits

1.1.3.1 CDO offers the following advantages:

- a) more efficient use of airspace and arrival route placement;
- b) more consistent flight paths and stabilized approach paths;
- c) reduction in both pilot and controller workload;
- d) reduction in the number of required radio transmissions;
- e) cost savings and environmental benefits through reduced fuel burn;
- f) reduction in the incidence of controlled flight into terrain (CFIT); and
- g) authorization of operations where noise limitations would otherwise result in operations being curtailed or restricted.

1.1.3.2 Depending on the airspace concerned, and the method of CDO facilitation chosen, the benefits of CDO will be optimized by a review of the airspace configuration for CDO, taking into account separation and sequencing requirements. The design and operation of both strategic and tactical deconfliction measures should take into account the profile envelopes expected to be followed by the range of aircraft using the procedures, in order to facilitate CDO to the greatest extent.

1.1.3.3 If ATC were to lose the flexibility to fully optimize sequencing and management of arrival flows, there could be a risk of reduced capacity and efficiency. Thus CDO should not be achieved at the expense of safety, capacity, flight efficiency or expedition and should be considered as being “the art of the possible” and, while highly desirable, it is not to be achieved at any cost.

1.1.3.4 Early sequencing of aircraft can assist in increasing both the frequency and duration of CDO performed, especially during periods of high traffic density.

1.1.3.5 The objective of this manual is to provide the guidance necessary, including a concept of operations, for aviation stakeholders to standardize and harmonize the implementation of CDO. Use of this guidance material should minimize the proliferation of definitions and concepts of “controlled descent” and should enhance safety by providing

information on commonly used procedures. Additionally, standardization of procedures is expected in the form of amendments to the *Procedures for Air Navigation Services — Aircraft Operations* (Doc 8168). Updates to this manual are expected in light of future developments, e.g., with the introduction of advanced supporting tools to further optimize maturity of CDO.

1.1.4 Concepts of operation

1.1.4.1 The *Performance-based Navigation (PBN) Manual* (Doc 9613) includes the following general statement related to the airspace concept:

“An airspace concept may be viewed as a general vision or a master plan for a particular airspace. Based on particular principles, an airspace concept is geared towards specific objectives. Airspace concepts need to include a certain level of detail if changes are to be introduced within an airspace. Details could explain, for example, airspace organization and management and the roles to be played by various stakeholders and airspace users. Airspace concepts may also describe the different roles and responsibilities, mechanisms used and the relationships between people and machines.”

1.1.4.2 CDO can enable several specific strategic objectives to be met and should therefore be considered for inclusion within any airspace concept or redesign. Guidance on airspace concepts and strategic objectives is contained in Doc 9613. Objectives are usually identified by airspace users, ANSPs, airport operators as well as by government policy. Where a change could have an impact on the environment, the development of an airspace concept may involve local communities, planning authorities and local government. Such involvement may also be the case in the setting of the strategic objectives for an airspace. It is the function of the airspace concept and the concept of operations to respond to these requirements in a balanced, forward-looking manner, addressing the needs of all stakeholders and not of one of the stakeholders only (e.g. the environment). Doc 9613, Part B, Implementation Guidance, details the need for effective collaboration among these entities.

1.1.4.3 The strategic objectives which most commonly drive airspace concepts are:

- a) safety;
- b) capacity;
- c) efficiency;
- d) access; and
- e) environment.

1.1.4.4 To illustrate, for an environmental policy there are several considerations which may drive the decisions. The environmental goal can be noise abatement, increased fuel efficiency and, hence, reduced emissions, or some combination of these. This could apply to both arriving and departing aircraft. CDO design needs to take into account issues such as the flight paths of departing aircraft, where uninterrupted climb is the most fuel efficient, the need to avoid populated areas and to accurately adhere to noise abatement routes. Also any dedicated take-off techniques that may be required or employed need to be considered. One or a combination of these issues in procedure design can be used to achieve the environmental goal. There may be trade-offs or synergies between these requirements.

1.1.4.5 In developing an airspace concept for the implementation of local CDO, implementation time might be an important constraint, reducing the phases of flight to which CDO is being initially applied. Additionally, limiting the changes to navigation requirements may reduce the implementation time frame.

1.1.4.6 With the need to ensure that CDO does not compromise safety and capacity, it may not always be possible to fly fully optimized CDO. As well, it may be necessary to stop a descent and maintain level flight for separation or sequencing purposes. The aim should be, though, to maximize CDO to the extent possible, whilst not adversely affecting safety and/or capacity. As designs improve, CDO using laterally and/or vertically fixed routes should become possible in increasingly dense traffic scenarios. Implementation of advanced ATM tools for separation, sequencing and metering should further improve CDO availability.

1.1.4.7 A CDO that is facilitated by the controller providing timely estimates of distance-to-go information to the pilot when being vectored may only be possible for lower altitudes and may offer less than fully optimal performance improvement. Such vector-based facilitation of CDO still offers worthwhile efficiency and improvements.

1.1.4.8 Arriving and departing traffic are usually interdependent, and the airspace design supporting CDO should ensure that both arriving and departing flights can achieve fuel-efficient profiles. Balancing the demands of capacity, efficiency, access and the environment is a most demanding task when developing an airspace design.

1.1.4.9 The following examples of different strategic objectives that need to be addressed in a balanced way are provided in Doc 9613:

Safety: The design of RNP instrument approach procedures could be a way of increasing safety (by reducing CFIT).

Capacity: Planning the addition of an extra runway at an airport to increase capacity will trigger a change to the airspace concept (new approaches to SIDs and STAR required).

Efficiency: A user requirement to optimize flight profiles on departure and arrival could make flights more efficient in terms of fuel burn.

Access: A requirement to provide an approach with lower minima than supported by conventional procedures to ensure continued access to the airport during bad weather may result in providing an RNP approach to that runway.

Environment: Requirements for reduced fuel use and emissions, noise preferential routes, specific take-off techniques, or CDO are environmental motivators for change.

1.2 CDO DESIGN OPTION

1.2.1 General

1.2.1.1 Accurate planning for an optimum descent path is facilitated by the pilot and/or the FMS knowing the flight distance to the runway and the level above the runway from which the CDO is to be initiated. This will allow an accurate calculation of flight descent path. Although CDO is optimized by using vertical navigation (VNAV) systems, these types of systems are not a prerequisite. Availability of wind and weather information helps to improve the accuracy of the flight descent path. Level information is readily available from the aircraft altimeter. Winds are usually provided in weather forecasts, local observations and pilot reports. However, exact distance or time to be flown to landing may not always be precisely known.

1.2.1.2 There are currently two methods for the design of CDO procedures based on “laterally fixed” routes. These require different methods to determine the flight distance to the runway threshold. These two design methodologies are identified as “closed path” and “open path” designs.

- Closed path designs are procedural designs whereby the lateral flight track is predefined up to and including the FAF/FAP and thus the exact distance to runway is precisely known. An example of a closed path procedure is an optimized profile descent (OPD) associated with a STAR terminating at a point that defines a part of an instrument approach procedure (IAP) and the STAR is thus directly linked to that IAP. Closed path designs support CDO directly and permit very precise distance planning allowing the FMS to accurately implement automated optimized descents.
- Open path designs are designs where the procedure finishes before the FAF/FAP.

1.2.1.3 Two main types of open paths exist:

- a) the first ends in a downwind leg leaving the controller to clear the aircraft to final;
- b) the second option is where the design delivers aircraft into a operational environment where approach sequencing is undertaken by holding patterns and vectoring. In this option, CDOs can only be planned to the metering fix, and the controller will need to estimate and communicate to the pilot, to the extent possible, distance-to-go information to the runway threshold if the CDO is to be continued beyond the point at which the preplanned CDO path ends. The pilot will use such distance estimates to determine the optimum descent rate to achieve a continuous descent to the FAF/FAP.

1.2.1.4 Other CDO design methods incorporating more advanced features including 4D navigation such as business trajectories are identified in SESAR, as are tailored arrivals in NextGen. These are still under development and are being shown in this manual (see Attachment A) as future design options only. Typically, these future CDO designs will require airborne and ground-based planning tools in order to support the planning and execution of continuous descent from cruising levels to touchdown. This could potentially involve several ATC units and sectors. Such CDO will take account of other air traffic as well as environment constraints and will use data link for the transfer of profile clearance and meteorological data. The following expands upon the closed path and open path design methods.

1.2.1.5 Closed path design (Figure 1-1)

The closed path design comprises a fixed route and a specific distance to the runway that is known prior to start of the continuous descent operation. The procedure may be published with crossing levels, level windows and/or speed constraints. The design of the closed path may comprise the STAR and (initial) approach phases of flight until the FAF/FAP.

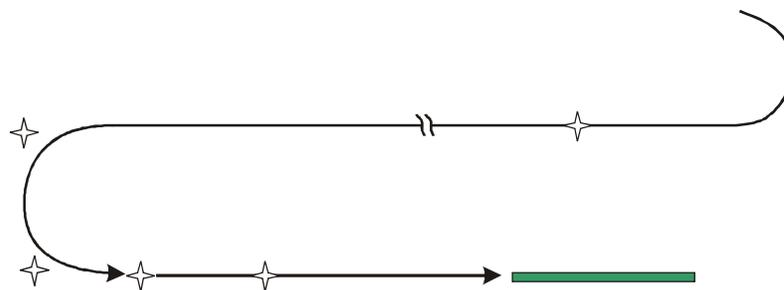


Figure 1-1. Closed path design

1.2.1.6 Open Path design

In an open path design a portion, or all, of the route consists of vectoring. The specific distance to runway threshold is not known prior to start of the CDO.

a) Vectored CDO procedure (Figure 1-2)

The aircraft is vectored, and the pilot is given an estimate of distance-to-go to the runway threshold. Clearance to commence descent is at the discretion of the pilot.

Note.— See 2.2.10 concerning use of phraseologies.

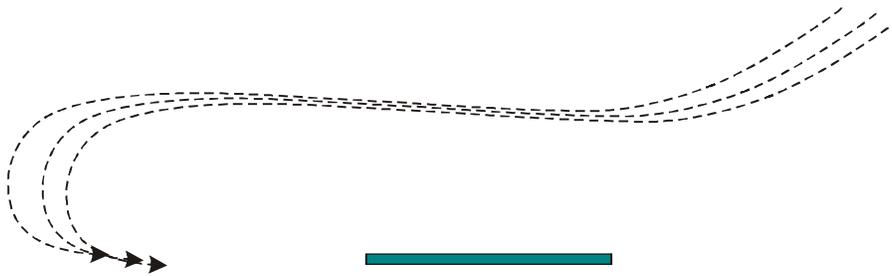


Figure 1-2. Vectored CDO procedure

b) Open CDO procedure to downwind (Figure 1-3)

This operation is based on a combination of a fixed route delivering aircraft to a vectoring segment, normally as an extension of the downwind leg to the FAF/FAP.

Note.— See the Quality Assurance Manual for Flight Procedure Design (Doc 9906, Volume I) for guidance on the quality assurance process for procedure design.

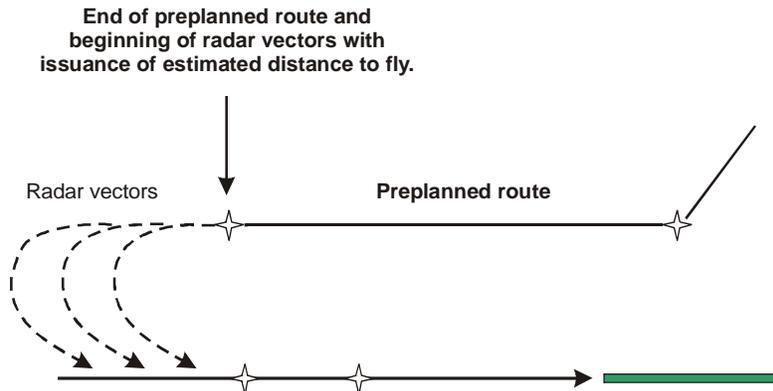


Figure 1-3. Open CDO procedure to downwind

1.2.1.7 Sequencing methods

Except in very low traffic density situations, some type of sequencing is usually required in order to maintain optimum landing rate. The following three sequencing methods can be applied to both types of CDO:

- a) Automated sequencing methods — Use of automated sequencing systems such as required time of arrival, traffic management advisory displays and relative position indicators. Such systems provide for efficient planning adjustments to be made to aircraft trajectory prior to beginning a CDO procedure. Automated sequencing methods are rapidly evolving and will increasingly play an important role.
- b) Speed — Speed control is most effective when a small correction is made early in a procedure and given time to take effect, or, when speeds are a part of the procedure. Speed control allows for predictable performance and is done to establish and maintain separation, and ensure consistent performance between different aircraft. Small speed adjustments can allow the aircraft to stay on a predefined closed path. Large speed adjustments may be counterproductive when following aircraft also need to be slowed to match and will require the aircraft to depart from efficient aircraft flight configurations.
- c) Vectoring — Vectoring is the most flexible way to sequence arriving traffic and maintain capacity. It is also the most frequently used method. Vectoring, however, provides the least advanced predictability to pilots with respect to flight path distances and may require pilots to respond to a situation rather than to plan ahead. Providing the pilot with information on estimated distance-to-go can help to mitigate uncertainty. Aircraft may be on a planned open path vectoring procedure or may be vectored off a closed path procedure in order to establish or maintain sequencing and spacing. In closed path CDO small speed adjustments should be considered first, preferably before the aircraft is vectored off the procedure. Remaining on the procedure will allow the FMS to maintain distance calculations.

1.2.1.8 Path stretching method/design (Figure 1-4)

1.2.1.8.1 Path stretching method/design is a planned vectoring path that has predetermined waypoints known to the FMS, pilot and ATC. The procedure can be issued to increase separation while allowing the FMS to fly the aircraft on the CDO. Path stretching may be used in addition to speed control methods.

1.2.1.8.2 Point merge sequencing method. With this technique, aircraft follow an RNAV routing, which generally includes a level flight arc segment until receiving a “direct to” routing to a merge point. The pilot may execute a CDO prior to the merge point arc, maintain level flight whilst following the arc and continue with CDO when cleared to the merge point. When traffic levels permit, the aircraft would be cleared direct to the merge point rather than establishing on the arc. See Figure 1-5.

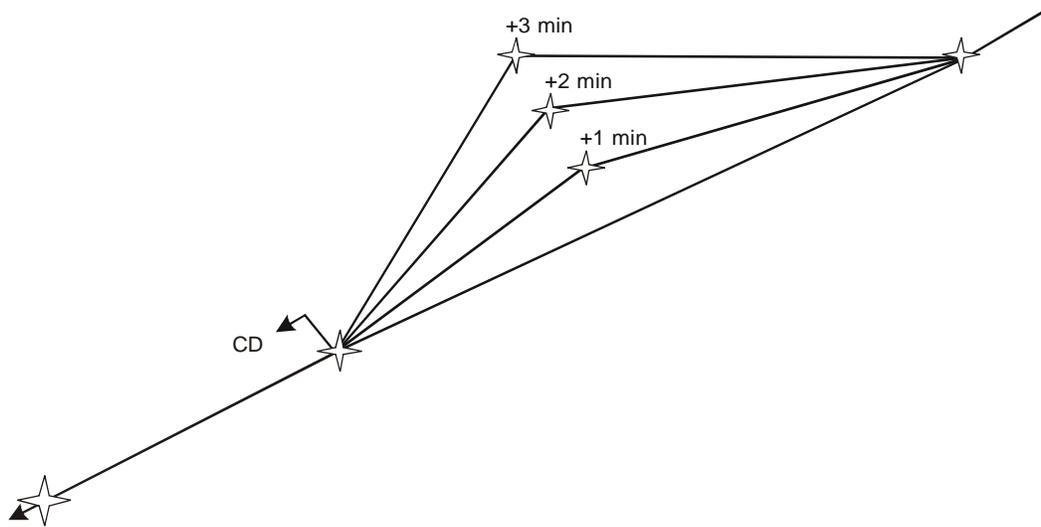


Figure 1-4. Path stretching method/design

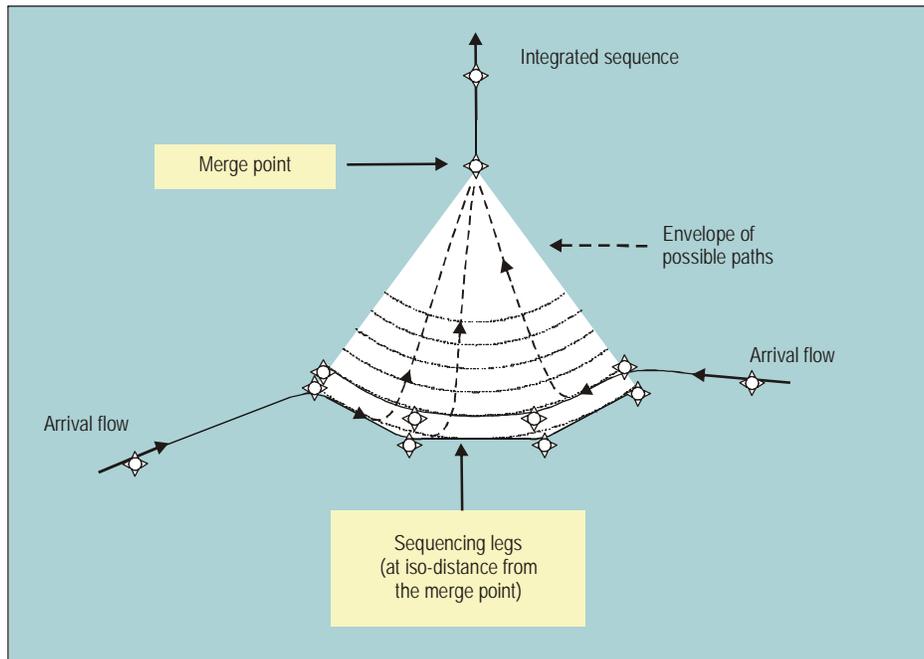


Figure 1-5. Point merge system

1.3 BASIC DESIGN EXAMPLES

1.3.1 Initial steps

1.3.1.1 Design of both “closed path” and “open path” CDO procedures should begin with a planned optimum lateral flight path. This path may be influenced by a number of factors, such as environmental constraints and concerns, flight paths of other air traffic departing the destination airport or flight profiles into and out of adjacent airports, aircraft navigation capability, traffic merging requirements, airport agreements, traffic flow rates, airspace sectorization and terrain.

1.3.1.2 To the extent possible lateral flight paths should minimize required distances to be flown. After a basic lateral path is laid out, any required flight level/altitude constraints should be added to the path. Such levels should be the minimum necessary to avoid terrain and other air traffic flows, comply with airport or environmental agreements, and meet ATC coordination requirements. After the preliminary path and levels are laid out, the path may have to be modified to comply with other required constraints. Several iterations of path/level modifications may have to be developed before an optimum path to the runway is devised. For a closed path design this will represent the shortest optimum distance to the runway. For an open path design this will serve as the basis to decide at which point vectoring should routinely commence.

1.3.1.3 To maximize the potential for acceptance of the proposed CDO, the project should involve representation from a broad cross-section of the stakeholders including operators, ATC, procedure designers, pilots, airspace planners, local environmental groups, etc. A suitable methodology to approach the development is provided in Doc 9613.

1.3.2 Closed path CDO design example

1.3.2.1 Figure 1-6 provides a simple example of a basic (OPD) closed path CDO with further detailed examples of both optimized and path stretch enhancements. To the extent possible, the lateral track should be chosen to minimize the track miles to be flown. Figure 1-6 assumes a continuous descent to the capture of the final approach. This is normally only achievable with a closed path CDO. However, this can also be adapted to the design of open procedures up to the point where radar vectoring is undertaken. The layout has the broadest possible level ranges and should thus accommodate virtually all types of aircraft without restriction. As the selected level ranges are so broad, the example design may require too much airspace and conflict with other air traffic flows and terrain. In areas with terrain constraints, airport agreements, airspace restrictions and conflicting air traffic flows, a more refined or optimized development will be required, including extensive modelling and simulation, in order to develop a procedure flyable by the broadest range of aircraft while minimizing conflicting traffic flows and the impact on airspace geometries.

1.3.2.2 However, where the airspace can support descent profiles between 2 and 3.3 degrees, there will be little requirement for modelling and therefore in many areas of low density operations the example below may serve as an easy-to-implement model.

1.3.2.3 The example shows a STAR linked to an instrument approach in an optimized CDO procedure and should allow most FMSs to perform fully automated lateral navigation/vertical navigation (LNAV/VNAV) descent. Most instrument approaches have a FAF/FAP, an intermediate fix (IF) and an initial approach fix (IAF). The STAR terminates at an IAF at an “at or above” level that matches the IAF level. This allows the FMS to link the STAR with the approach procedure. Instrument approach levels from the runway threshold are generally designed to allow for a 3-degree descent path (approximately 320 ft/NM) and have a shallower segment in the IF portion to allow aircraft configuration to a fully stabilized final descent.

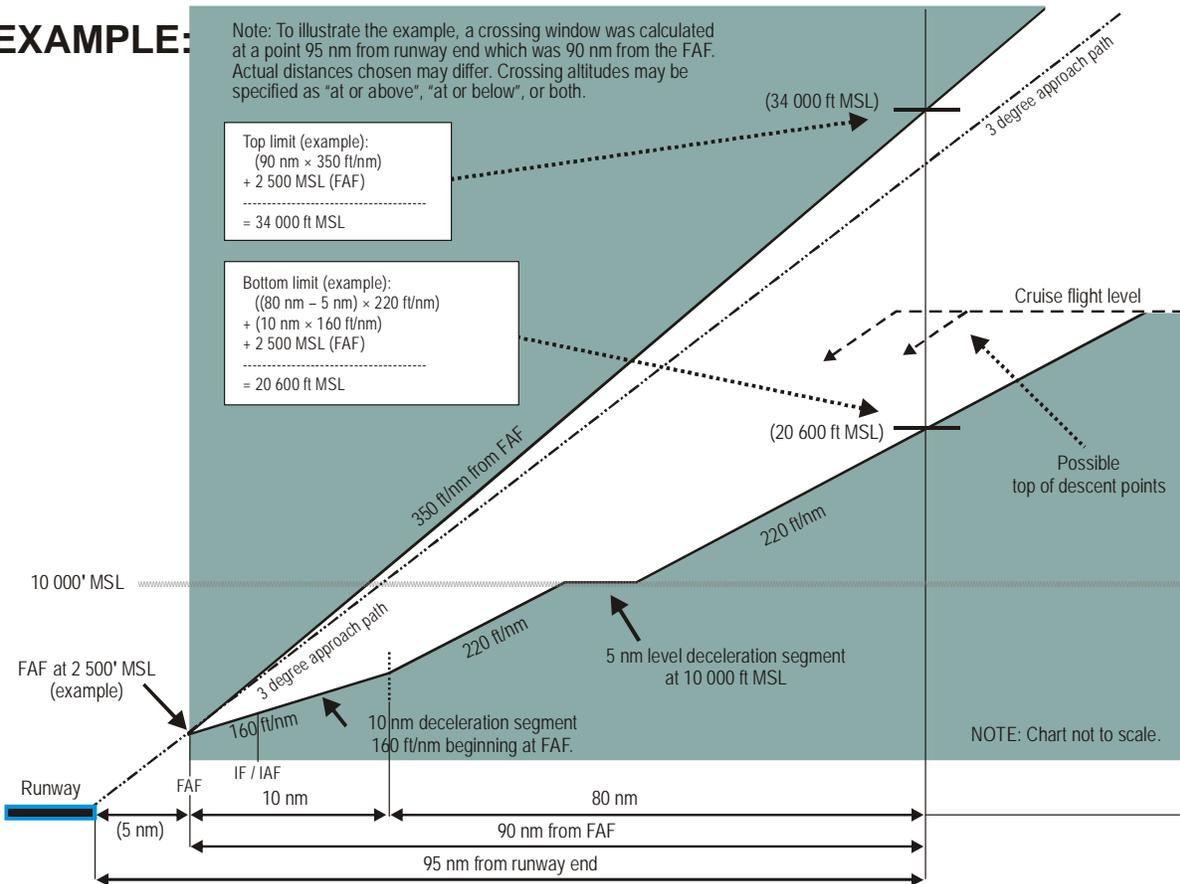
EXAMPLE:

Figure 1-6. Instrument approach in an optimized CDO procedure

1.3.2.4 STAR level windows or procedure height constraints should, to the greatest extent possible, be designed to allow most aircraft to descend unimpeded. The windows are defined by an upper limit and a lower limit. An upper limit is defined as an "at or below" flight level/altitude and is usually set to allow separation from other air traffic flows or to establish crossing points for ATC coordination points. An upper limit starting at the runway threshold and rising at a rate of 350 ft per NM is sufficient for most aircraft.

1.3.2.5 For instance, if an upper height/level window is needed for crossing air traffic flows at a distance of 90 NM from the FAF elevation of 2 500 ft MSL, the upper altitude limit is calculated as follows:

$$(90 \text{ NM} \times 350 \text{ ft/NM}) + 2\,500 \text{ ft (FAF elevation)} = 34\,000 \text{ ft MSL.}$$

In this example, the "at or below" altitude should be no lower than "at or below 34 000 ft".

Note.— The altitude would need to be recalculated and depicted on charts as a flight level.

1.3.2.6 The lower limit shown in Figure 1-6 is defined as an "at or above" level and although set as low as possible will often be set for terrain clearance, to comply with airport agreements, to provide separation from other air traffic flows, and for ATC coordination purposes. The lower window takes into account the fact that in normal conditions and in a

clean configuration most modern aerodynamically efficient aircraft may not decelerate sufficiently for landing when descending at angles much above 2 degrees. In some conditions (e.g. a tail wind) and at a higher starting speed (>200 knots) angles of around 1.5 degrees (or less) may be required to decelerate a modern aircraft that is in a clean configuration. A lower level window is calculated from the FAF level and rises at a rate of 160 ft per NM for 10 NM and then at a rate of 220 ft/NM to an altitude of, for example, 10 000 ft MSL. In this instance, at 10 000 ft MSL a level segment of 5 NM is added to allow for aircraft deceleration and then continues to rise with 220 feet per NM. For instance, if a lower limit is needed 90 NM from the FAF and the FAF is at an altitude of 2 500 ft MSL, the calculations would be as follows:

$(10 \text{ NM} \times 160 \text{ ft/NM}) + (80 \text{ NM} - 5 \text{ NM (level segment at 10 000 ft)} \times 220 \text{ ft/NM}) + (2 500 \text{ MSL (FAF)}) = 20 600 \text{ ft MSL}$. Thus the “at or above” altitude at 90 NM from the FAF should be no higher than “at or above 20 600 ft”. Thus, in the examples illustrated above, an upper level window of “at or below 34 000 ft” (expressed as a flight level), and a lower level window of “at or above 20 600 ft” (expressed as a flight level) would meet the requirements to enable CDO.

1.3.2.7 The formulas are:

Upper level window limit
Equals (distance from FAF x 350 ft/NM) + elevation of the FAF

Lower level window limit
Equals (distance from the FAF desired for deceleration x 160 ft/NM) + for crossing altitudes of 10 000 ft MSL or less equals (distance from FAF – distance from the FAF desired for deceleration x 220 ft/NM) + FAF level

For crossing altitudes more than 10 000 ft MSL equals (distance from the FAF desired for deceleration x 160 ft/NM) + (((distance from FAF – distance from the FAF desired for deceleration) – 5NM) x 220 ft/NM) + FAF level. See Figure 1-6.

Such shallow angles of descent close to the FAF will reduce the height above the ground (thereby increasing noise on the ground) and may not be possible due to airspace limitations or other operational and structural constraints (e.g. proximity of other airports, airspace limitations, interactions with departing traffic, terrain, etc.). Often therefore aircraft descend at a high angle and decelerate to their final landing speed and configuration using drag devices. Whilst this generates more airframe noise it is offset to some extent by the increased height above the ground. This compromise needs to be studied locally.

1.3.3 Modified design scenarios

The basic design above may need to be modified to avoid high terrain or other air traffic flows, to comply with airport or environmental agreements, and/or with ATC coordination procedures. If the basic design needs to be modified, additional calculations should be made to ensure that the largest number of aircraft can fly the procedure with the least number of restrictions. Close coordination between ANSP, aircraft operators and system designers is essential.

1.3.4 Flight simulations

Feedback from flight simulations is one way to ensure that the proposed design does not adversely affect aircraft and/or that it can facilitate the availability of CDO to the majority of the expected aircraft fleet. See Figure 1-7.

- Monte Carlo: Iteratively simulate the effects of random factors by covering all possible values of input parameters and their combinations

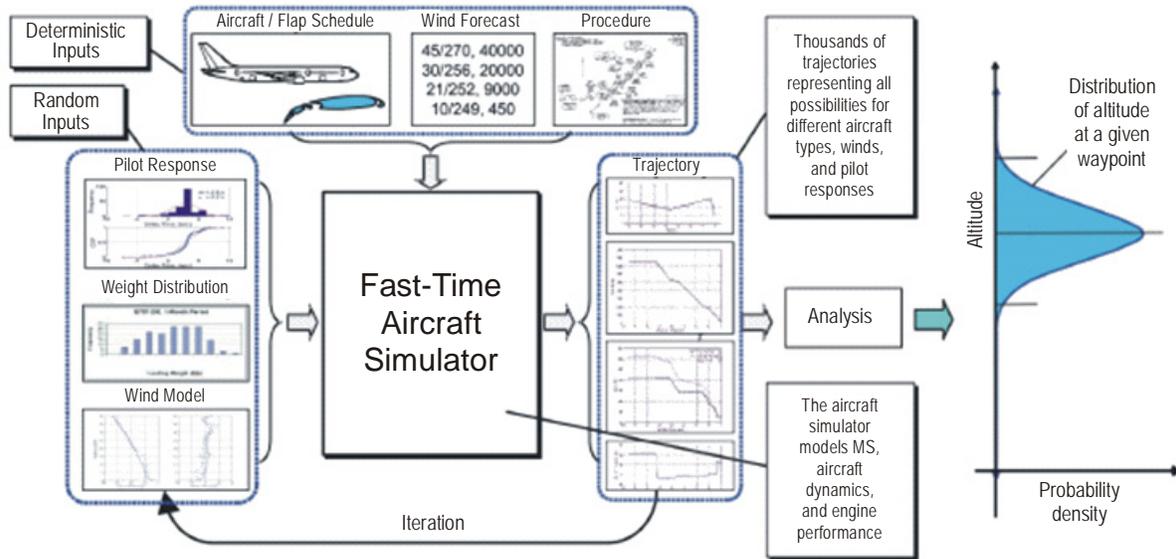


Figure 1-8. Simulation results for typical arrival route

Vectors would normally be initiated from a metering fix. Where CDO can be implemented from cruising levels to the metering fix, the guidance provided in 1.3.2, Closed path CDO design example, could be used for the design down to the metering fix.

- b) Open path procedure permitting CDO to downwind

This procedure design provides sequencing by way of the controller timing the aircraft's turn on to final approach. The CDO can be planned to the downwind terminal waypoint (DTW) (see Figure 1-9). Basic techniques, as for the closed path procedure, should be used for designing the procedure down to the DTW with the level of DTW replacing the runway elevation.

1.3.7 General considerations

1.3.7.1 CDO should be designed and implemented such that it neither conflicts with the optimal airport arrival rate (AAR), nor that it unacceptably and adversely affects other non-CDO arriving aircraft, overflying aircraft or departing traffic. There are many factors influencing the ability to maintain CDO whilst maintaining the AAR. These include whether the lateral guidance is a fixed route or involves vectoring, the length of the fixed route and whether speed control is necessary to support sequencing. Additional tools for ATC to manage the spacing and sequencing process may increase the level of CDO achieved.

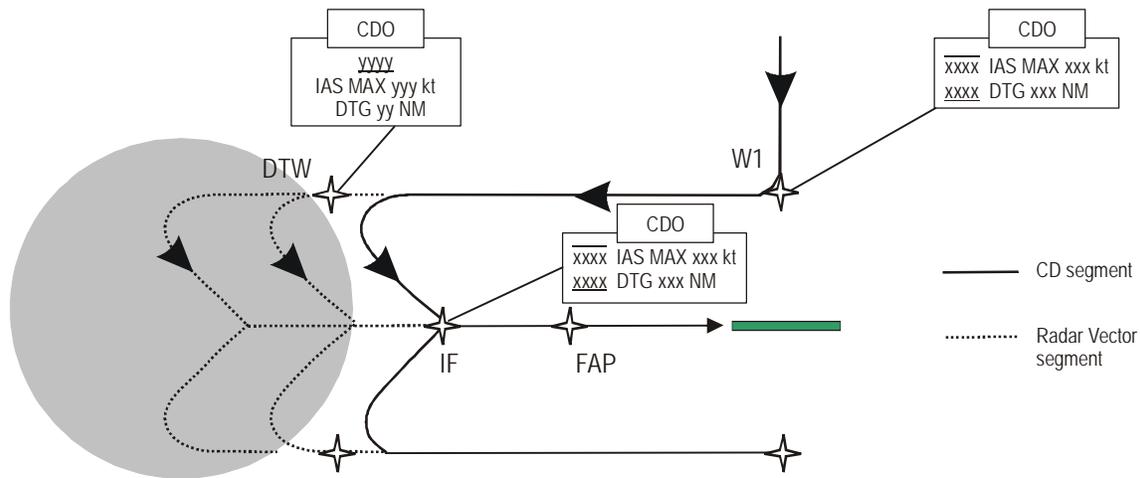


Figure 1-9. Simulations with a range of variables

1.3.7.2 A step-by-step implementation strategy is recommended. The implementation process needs to include a safety assessment that considers the effect of the changeover between operations with and without the use of CDO. Any changeover between different forms of CDO procedures (e.g. from vectoring-based to procedure-based and vice versa) should be addressed as part of a safety assessment. Properly designed CDO procedures should allow for a seamless transition to non-CDO, thus allowing CDO to be conducted with minimal risk during increasing percentages of time.

1.3.7.3 There is an expectation that future automation systems, in conjunction with the use of improved aircraft and ground systems and flight procedures, will enable a more generalized implementation of optimized CDO procedures during the busiest traffic periods. The main element in this development is the capability to sequence and merge the incoming traffic efficiently while optimizing CDO within the constraint of AAR. The higher the level at which CDO is initiated, the greater the demands on the supporting tools.

1.3.7.4 Where CDO will affect more than one ATC unit, e.g. in the case of CDO initiated at cruising levels, appropriate letters of agreement between the units covering such operations will be required. Ultimately, CDO may take the form of trajectory negotiations based on data communication exchanges between the ground systems, airborne systems, individual aircraft and traffic flow management. Research is underway to develop tools for managing the traffic at high traffic density levels while facilitating CDO. Such tools may include ground-based trajectory predictors supported by a data linked profile and meteorological data exchange. Until such time, publication of STARs with efficiently defined lateral paths and flexible descent profiles with appropriate "level windows" to accommodate conflicting traffic, coupled with CDO-compliant tactical techniques, will allow the aviation community to realize many of the operational and environmental benefits of CDO.

Chapter 2

SPECIFIC STAKEHOLDER ISSUES

2.1 GENERAL

This chapter addresses specific stakeholder issues. As the design process is a collaborative effort, all stakeholders need to read this chapter in its entirety.

2.2 AIRSPACE/PROCEDURE DESIGN

2.2.1 General

The guidance in this paragraph should be used in conjunction with the arrival and approach requirements details in PANS-OPS, Volume II (Doc 8168). To the extent possible, a CDO procedure should be designed with the following in mind:

- a) a low-power performance descent path segment is the path that results from a minimum thrust power setting on all engines for any given aircraft configuration, weight and atmospheric conditions. The performance descent path angle will vary with respect to the ground reference.

Note.— Use of a geometric descent path is seen as a possible option. A geometric descent path segment is a fixed angle descent path with respect to a ground reference. It will likely not be a minimum-power descent path for any given aircraft weight, configuration and atmospheric conditions; additional thrust or drag may be required to keep the aircraft on the geometric path. Geometric descent path segments may result from altitude or speed constraints along the path.

- b) level restrictions should not overly constrain the continuous descent path. Rather, the path should result from a clearly defined end point, with only those minimal constraints necessary to meet the level restrictions derived from the airspace concept and design. Minimum, maximum or level crossing windows should be used whenever possible rather than hard constraints as this reduces workload for manual continuous descent execution and allows for minimum engine thrust descents.
- c) aircraft operating parameters will also act as constraints on the continuous descent path. In the context of normal operations, descent is followed by approach and landing. The aircraft configuration and the operating conditions will introduce constraints that should be taken into account in the procedure design.

2.2.2 Collaboration and standardization

2.2.2.1 A design of CDO and any airspace changes that may be needed to facilitate it needs to be a collaborative process involving the ANSP, aircraft operators, airport operators, the aviation regulator and, through appropriate channels, environmental entities, as necessary.

2.2.2.2 Expertise in FMS performance and flight procedure coding conventions (PANS-OPS, Volume II, Part III, Section 2) should be included on the design team as arrival procedures will be stored in a navigation database. Specifically, when procedures will involve demanding lateral manoeuvring, there may be a need for prior consultation with navigation database specialists.

2.2.2.3 As in all instrument flight procedures, the design should be standardized and conform to accepted charting and database conventions in order to support the standardization of cockpit procedures.

2.2.3 Speed restrictions

2.2.3.1 Specific speed restrictions, often 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. Aircraft/FMS-specific limitations should also be taken into account.

2.2.3.2 Proposed permanent speed restrictions need to be coordinated between all stakeholders prior to finalizing them. In general, speeds from higher levels should not be less than 280–290 kts IAS. An example chart notation could be "... maintain 280 kts IAS until leaving 10 000 ft MSL". Pilots are expected to programme their FMS to pick up the speed schedule of 280 kts as the aircraft descends from the Mach regime.

2.2.3.3 With prior planning, speed control can be factored in by the flight crew and accomplished without use of drag or level flight.

2.2.4 Transition altitude — transition level

2.2.4.1 If a CDO starts above the transition level (TL), a buffer should be established by the procedure designer and added to the minimum levels along the path. This buffer will be calculated based upon the aerodrome historical pressure altitude range. The implications of TL for local CDO design should be collaboratively agreed and reviewed in the light of experience.

2.2.4.2 In order to optimize CDO performance, it is recommended that transition altitudes (TA) be established as high as possible, e.g., 10 000 ft or higher.

2.2.5 Database coding

2.2.5.1 Unless operational requirements dictate otherwise, the following database conventions should be used:

Closed path CDO procedures: These procedures should be coded with track to fix (TF) legs and fly-by waypoints. STARs that terminate with a link to an instrument approach procedure should terminate at a fly-by waypoint. STARs that terminate with vector-based legs may be coded with fix to manual termination (FM) or heading to manual termination (VM) path terminators.

2.2.5.2 Where the expected fleet has sufficient capability, the use of the radius to fix (RF) leg will provide a controlled turn performance with reduced sequencing timing errors and an improved VNAV accuracy.

Open path CDO procedures: After the DTW an FM path terminator should be coded. If ATC requires a defined path, a VM path terminator can be used instead.

2.2.6 Publications and charting issues

General

2.2.6.1 Where CDO is expected to be flown during the arrival or approach to an airport, it is recommended that the specific information relating to the CDO be published through established channels to ensure that all stakeholders are aware. The provision of distance-to-go information will provide assistance to the pilot in planning the trajectory to achieve CDO.

2.2.6.2 Two types of charts may be involved in CD operations:

- a) STAR; and
- b) Approach chart used for a procedure designed for a CDO.

2.2.6.3 Unless specifically required as a part of the procedure design, there is no need to provide specific level windows or speed restrictions for CDO on STAR charts.

2.2.6.4 Any speed and altitude restrictions applicable at or beyond the IAF should be clearly depicted on the chart.

2.2.6.5 Level restrictions should be expressed using level windows (with minimum and maximum levels), or by “at or above” or “at or below” constraints.

2.2.6.6 If CDO is only applicable to a part of a procedure, this should be depicted in an obvious and unambiguous manner, indicating on the chart the beginning and the end of a path where a continuous descent technique may be applied.

2.2.6.7 The CDO may be indicated with appropriate text on the chart or by the procedure designation, e.g. KARLAP (CDO).

2.2.7 Flight operation

General

2.2.7.1 The optimum CDO is flown as a continuously descending flight path with a minimum of level flight segments and engine thrust/engine thrust changes and, as far as possible, in a low drag configuration. Before interception of the final approach segment, aircraft speed and configuration changes have to take place, including the extension of slats, flaps and landing gear. This configuration process should be managed with care in order to minimize the risk of unnecessary thrust settings and should conform to the standard procedures for configuring the aircraft for landing as detailed in the aircraft operating manual. If available, and whenever possible, the vertical path as calculated by the FMS should be used.

2.2.7.2 Specifically, techniques that enable a fuel-efficient (minimum thrust), optimum descent and approach should be used wherever and whenever possible. The total energy of the aircraft at high altitude can be used most efficiently during descent with minimum thrust and drag. However, the pilot should have the flexibility to manage the aircraft's speed and rate of descent within the constraints of the procedure. For aircraft equipped with FMS with VNAV capability, an optimum descent can be planned and executed with a fixed lateral flight path stored in the navigation database.

2.2.7.3 The instrument flight procedure may have been designed to facilitate CDO all the way to the FAF/FAP, from a merge point to the FAF/FAP or via one or more merge points to the downwind leg for vectoring to the IAF or the

IF/FAF/FAP. The actual procedure to be flown should be clearly indicated on the appropriate chart. The availability of the full CDO may depend upon prevailing traffic density levels and on controller workload.

2.2.7.4 Additionally, the pilot's ability to conduct a CDO depends also on the ATC clearance to be followed, either tactically or by published procedures. The pilot-in-command should attempt to conduct a continuous descent within operational limits when feasible. The final authority over the operation of the aircraft will always remain with the pilot-in-command, and stabilization of the aircraft during the final approach should never be compromised.

Note.— Reference is made to Annex 6, Part I, 4.5.1, concerning duties of the pilot-in-command.

2.2.8 Transition level

Where a continuous descent starts above the TL, and there is a significant difference between the aerodrome QNH and the standard pressure, the vertical flight path will be affected and a temporary change of the vertical descent rate may be observed.

2.2.9 Cockpit workload

2.2.9.1 Cockpit workload should be considered in the design of any CD procedure. A procedure designed for CDO should keep the workload required during a continuous descent within the limits expected for normal flight operations. The lateral and vertical flight path generated by the on-board computer should be capable of being easily modified by the flight crew, using normal data entry procedures to accommodate tactical interventions by ATC as well as variations in wind speed and direction, atmospheric pressure, temperature, icing conditions, etc. In certain flight regimes, for example, during vectoring, such modification may not be possible, causing a significant decrease in the ability of the aircraft to accurately fly a fully optimized profile.

2.2.9.2 ATC should provide the pilot with timely information, tactical spacing and operational flexibility in order to facilitate a CDO. Additional speed or level constraints may increase pilot workload and reduce procedure effectiveness.

2.2.10 Phraseology

Phraseologies and associated procedures used by one State are described in Appendix 2.

2.2.11 Pilot training

Optimum execution of a CDO procedure may require additional action be taken by the pilot flying. Consequently, effective and precise execution of a CDO procedure may require procedure-specific issues to be briefed prior to starting the arrival. These may include the following:

- a) speed restrictions;
- b) level constraints or crossing restrictions;
- c) the level of automation to be used;
- d) the possible effect of wind, atmospheric pressure, altimeter setting and expected icing conditions;
- e) the effect of the transition level; and
- f) ATC phraseology.

2.3 ATC TECHNIQUES

2.3.1 General

2.3.1.1 Maximum effective execution of published CDO procedures using laterally and/or vertically defined routes requires flexible airspace design and sectorization, with sufficient room to allow the aircraft to descend in accordance with the parameters computed by the FMS. A flight path extension will place the aircraft below the optimum vertical path, and a shortening of the route will place the aircraft above the optimum vertical path. In the first case, more thrust may be required to achieve the desired arrival or approach descent profile; secondly, additional drag which can create both an increase in noise on the ground and an uncomfortable ride for passengers may be required to recapture the optimized profile or approach path.

Note.— The pilot-in-command can reasonably be expected to attempt, when feasible, to conduct a continuous descent within operational limits. The final authority over the operation of the aircraft remains with the pilot-in-command, as is the responsibility for never compromising the stabilization of the aircraft during the final approach.

2.3.1.2 As discussed in Chapter 1, there are two main types of CD procedure designs:

- a) closed path designs, where the specific distance to runway end is known prior to start of procedure; and
- b) open path designs, where the specific distance is not known prior to start of procedure.

2.3.1.3 Ground tracks of CDO based on vectoring will be more dispersed than those based on FMS-generated profiles, which are calculated on a fixed, predefined lateral route. The vector-based CDO procedure, which can also be flown by aircraft without an RNAV capability or FMS, requires specific operational knowledge and experience that can be easily gained. The controller should estimate the approximate track miles to be reported to the pilot, so that the pilot can plan for an optimum descent profile, based on several variables, including the expected route to be flown, wind effects, aircraft performance, pilot reaction time, et al. This has been shown to be a practicable task where it has been applied, even in high-density terminal airspace.

2.3.1.4 In the case of a vector-based CDO procedure the pilot will be flying the vertical profile with the rate of descent required to make good the height loss needed prior to the ILS glide path capture. The lack of automated support through the FMS may result in the need to concentrate more on the optimization of the descent profile, compared to a CDO procedure based on a predefined route. This need may conflict with other pilot responsibilities associated with approach and landing. The decision whether to act on the improved situational awareness provided by ATC will remain the pilot's prerogative. An assessment of the positive and negative workload effects for the entire descent should be undertaken and taken into account in the design of the procedure.

2.3.2 CDO and airport arrival rate (AAR) considerations

2.3.2.1 CDO should not compromise the AAR and should be considered as “the art of the possible” within the AAR constraint. Variations in aircraft performance, including descent rates, optimum descent points and speeds, may make it difficult in the near term to utilize CDO procedures fully on a published fixed route, while maintaining the maximum runway landing rate. Traffic demand may dictate tactical interventions by the controller on arrival flows so as to achieve the maximum landing rate. Presequencing of the traffic prior to the merge point is essential to achieve the maximum capacity when using closed path CDO procedures. The more effectively aircraft are sequenced and merged, the greater the likelihood that aircraft can maintain the optimum rate of CDO. Presequencing may be effected by tactical lateral path stretching (using vectoring or point merge techniques) and/or speed control.

2.3.2.2 During peak periods, depending on the runway configuration, the simultaneous use of two CDO procedures may not be compatible with parallel runway operations, due to the requirement for 1 000 ft of vertical separation in the intermediate segment of the approach. The lack of a horizontal segment in case of a CDO procedure may require dependent operations with longitudinal separation prior to intercepting the final approach. This can result in an associated decrease in capacity or the utilization of extreme shallow final approach intercept angles. This will allow controllers more time for surveillance and communication.

2.3.3 ATC training

2.3.3.1 Controllers should gain a thorough understanding of the operational benefits and consequences with regard to the conduct of CDO procedures, the profiles associated with CDO and in particular the type of CDO being controlled at their ATC unit. CDO requires specific operational training and knowledge. On-the-job training or realistic simulation exercises and recurrent training should be essential parts of the training process to ensure controller proficiency. Controllers should also understand the basis of the aircraft energy management and the environmental trade-offs inherent in CDO, especially as affected by speed control and path modification, and be aware of the need for unambiguous controller-pilot communications.

2.3.3.2 During the CDO procedure design phase or prior to flight trials, joint ATC and flight simulations will allow controllers and pilots to better understand the issues and limitations that they each face.

2.3.4 Controller workload

2.3.4.1 When vector-based CDO procedures are used, controller workload may increase in some areas and may decrease in others (e.g. level-off management). The provision of distance-to-go information to the pilot requires the controller to predict the actual flight path miles to be flown. As distance-to-go information cannot be automatically integrated into the predicted vertical path, the results achieved will be at best rough estimates of what an optimal path might be. Imposing speed or level restrictions may increase pilot workload and reduce procedure effectiveness. If necessary due to separation and/or spacing requirements or other relevant circumstances, the controller will issue an amended clearance with revised level or speed restrictions, thereby terminating the continuous descent.

2.3.4.2 Closed path CDO procedures have the potential to provide a predictable flight path, reducing the level of controller-pilot communications, and potentially reducing workload for both the controller and the pilot.

2.3.5 ATC facilitations

Different CDO options

2.3.5.1 CDO may start anywhere from the top of descent (TOD), on the STAR, or at or beyond the IAF. The start point of a continuous descent is a decisive factor in defining the way in which the procedure will be performed and in identifying when relevant actions need to be taken. It may also be the case that for an individual flight CDO can be facilitated down to a holding pattern and then again from the holding pattern to touchdown. Thus, there may be more than one segment of a CDO within a flight.

2.3.5.2 For optimized fuel efficiency and reduced emissions a CDO should start at the end of the en-route phase and be initiated at or prior to the TOD. An initial descent with minimum thrust setting should be seen as normal practice where and whenever possible.

Sequencing techniques in relation to CDO and optimal AAR

2.3.5.3 The application of CDO procedures in the air traffic system, including their impact on aircraft sequencing and landing rates, depends on the level of traffic density and types of flights involved. Application of the procedures could vary during hours of operation. From strictly an environmental standpoint, application of CDO procedures can be beneficial regardless of airport size. Except for very complex airspaces it should be possible to enable some degree of CDO to most airports.

2.3.5.4 While the use of a CDO will usually be seen as an environmental benefit whatever the size of the airport, the operational consequences should be considered for any application.

2.3.5.5 In collaboration with other operational stakeholders, ATC should be able to implement the best mix of facilitation techniques so as to suit present and future traffic scenarios. Where feasible, CDO using preplanned profiles should be available from as high levels as possible, using the full capability of airborne and ground-based systems. When traffic levels or operational requirements dictate otherwise, a reversion to vector-based CDO procedures or non-CDO procedures may be necessary.

2.3.5.6 ATC units should through collaboration make use of tactical opportunities to offer CDO from TOD and seek to optimize the number of and extent of CDO over time.

Letters of agreement

2.3.5.7 In preparation for the implementation of CDO, letters of agreement between affected ATC units and sectors should be reviewed and updated as necessary, taking into account that CDO may entail changes to both vertical and horizontal flight paths.

Chapter 3

CDO IMPLEMENTATION OVERVIEW AND PREREQUISITES

3.1 INTRODUCTION

This section offers a model process for implementing CDO. This implementation guidance is not meant to be a blueprint and may need to be modified to account for local requirements, issues and considerations. The collaboration process used when implementing CDO can be applied to progress other aircraft operational environmental initiatives.

3.1.1 CDO implementation principles

Before and during the implementation process, it is important that the principles below be followed:

- a) safety of operations shall not be compromised in any way;
- b) collaboration between ANSP, aircraft operators and the airport operator is essential;
- c) CDO down to FAP/FAF/IF/IAF may not always be appropriate. However, a hybrid approach of a CDO procedure to a specified level and waypoint followed by vectors to the FAF/final approach course may be a viable solution;
- d) CDO should not be considered in isolation but rather in the light of the total current operations, e.g., the implications for departures and any planned changes, such as implementation of airspace changes, RNAV 1/RNP 1 approaches or advanced automation systems;
- e) the effectiveness of a CDO procedure relies on clearances precluding early or late initiation of descent, using minimum thrust whenever possible, avoiding unnecessary level flight, and allowing the aircraft to fly at speeds and on paths that permit them to operate as efficiently as possible;
- f) an optimum CDO procedure requires a fixed lateral path and a preplanned vertical path allowing the aircraft to descend unimpeded. Published level restrictions should be defined so as to allow the aircraft to descend unimpeded;
- g) at higher levels, where noise is less important, improved fuel efficiency and emissions reductions become the main aims;
- h) energy management is critical to a successful CDO. Appropriate use of speed control can help; a small reduction in approach speed may reduce the noise impact significantly;
- i) a complete continuous descent from TOD is ideal and should be initiated whenever tactically possible;
- j) a partial continuous descent within individual sectors and at lower levels will still be worthwhile, with between 50 to 100 kgs fuel saved per flight;

- k) different CDO procedures/profiles to suit changing scenarios can be used at an airport. However, in such circumstances, appropriate ATC coordination agreements need to be established so as to avoid potential confusion;
- l) CDO is the art of the possible and should not adversely affect capacity. Start simple and build on experience; such an approach will prepare for new technologies;
- m) a CDO procedure should not cause a greater disadvantage for other operations when the entire operation is considered;
- n) assessing the performance baseline is an essential first step; and
- o) changes to aircraft flight tracks over the ground may require consultation with external entities, as part of local consent processes and/or legal procedures.

3.2 IMPLEMENTATION PROCESS DIAGRAM

3.2.1 Figure 3-1 shows a process for effectively implementing CDO.

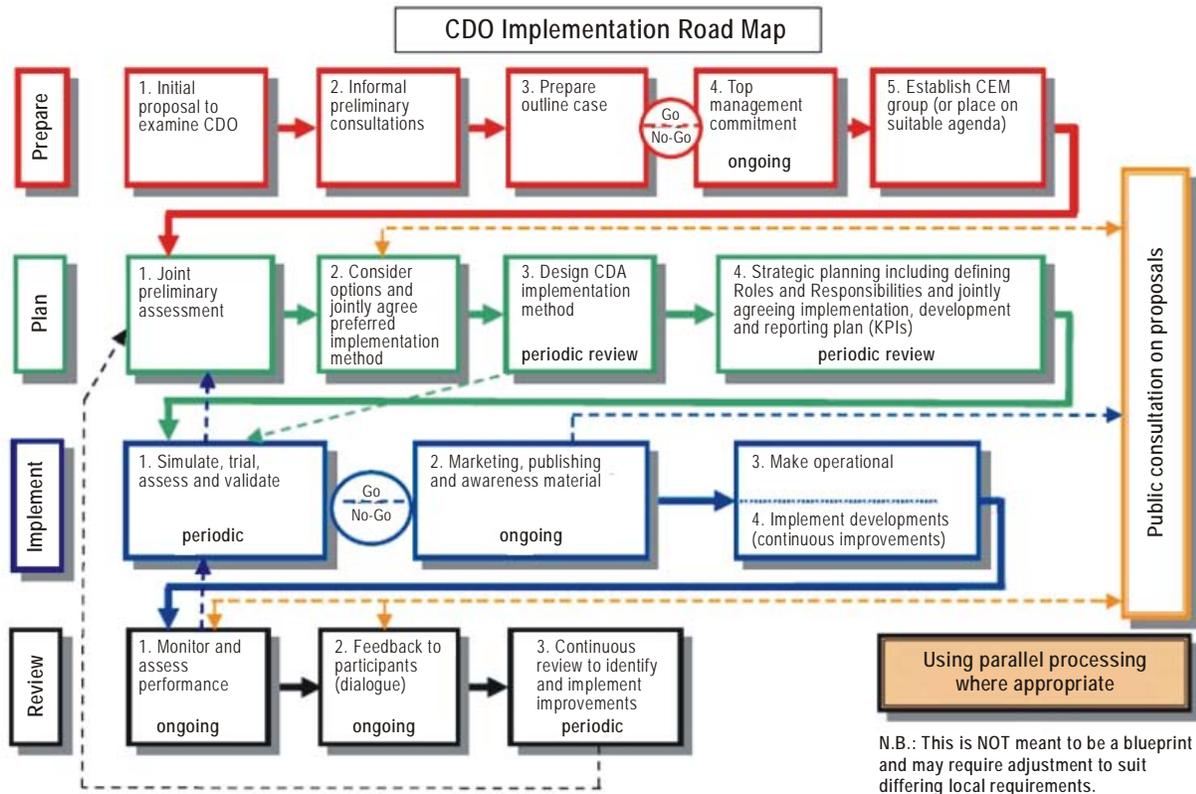


Figure 3-1. Implementation roadmap

3.2.2 Figure 3-1 addresses the totality of the programme from initial concept through planning, implementation and review. The early steps are primarily associated with education and winning support from senior management.

3.2.3 Concentrating on the steps needed when a go-ahead has been given, Table 3-1 provides a basis upon which a project management plan could be developed. Such a table could be part of a State PBN action plan.

Table 3-1. Project management plan

Item Name	Start Date	Due Date	Point of Contact	Status
Conceptual design				
Stakeholder review				
Revised design (apply criteria)				
Stakeholder review				
Desktop simulation (ground validation)				
Flight simulator evaluation (ground validation)				
ATC simulator evaluation (Flight track/radar track)				
Carry out initial safety assessment				
Stakeholder review				
Operational procedure and training review (ATC and flight crew)				
ATC systems review				
ATC/operational procedure documentation				
Stakeholder review				
Flight validation (trials)				
Update safety assessment				
Implementation decision				
ATC system adaptation and validation				
Training and notification				
Operational flight trials				
Procedure ready for use				
Clearance for operation decision				
Post procedure implementation analysis				
Environmental review				
Update safety assessment in the light of experiences				

3.3 IMPORTANCE OF EFFECTIVE COLLABORATION

3.3.1 Successful implementation of CDO requires full collaboration between all stakeholders. While the subject of CDO implementation could be placed on the agenda of an existing collaborative group, it is recommended that a CDO-specific collaborative group be established. This should include all stakeholders as members. Full CDO performance will not be achieved overnight; indeed CDO should be seen as a journey, not a destination.

3.3.2 Appendix 1 to this manual contains specimen Terms of Reference for a CDO Collaborative Implementation Group (CG) and a CDO Implementation Group (CIG).

3.4 COMMUNITY RELATIONS AND CONSULTATION

Introducing CDO may offer benefits in terms of reduced noise, but may also change the nature or locations of noise impacts. Whilst the majority of the populated area may benefit from reduced noise, there may be a minority for whom the noise increases. External consultation with interested parties may therefore be required at the option selection stage, and land-use planning zones may need to be altered. This consultation should be handled through established community relations channels, where they exist.

Note.— For example, introducing CDO-compliant STARs may result in concentrating flights over standard route centrelines. Facilitating CDO using merge point techniques, however, can change aircraft lateral profiles.

3.5 POLICY CONTEXT

3.5.1 Understanding the policy context is important for making the case for local CDO implementation and ensuring high levels of participation. CDO may be a strategic objective at international, State, or local level, and as such, may trigger a review of airspace structure. For example, noise contour production may already assume a 3-degree continuous descent final approach. Thus, even if noise performance is improved in some areas around the airport, it may not affect existing noise contours. Similarly, CDO may not affect flight performance within the area of the most significant noise contours, i.e., those depicting noise levels upon which decision-making is based. It is important not to raise unrealistic public expectations, but, at the same time, it is important to communicate successful implementation and positive performance.

3.5.2 In addition to a safety assessment, a transparent assessment of the impact of CDO on other air traffic operations and the environment should be developed and made available to all interested parties.

3.5.3 An initial simple or limited implementation of CDO should be seen as the first step towards continuing CDO improvements. A no-blame culture will be essential to allow open and frank discussion on safety and performance issues in order to underpin improvements.

3.5.4 For some airports, because of complexity of operations, adverse trade-offs or airspace restrictions, CDO may not be possible. In such cases, it is important to compile a report detailing the process used to arrive at the final conclusions and the reasoning for rejecting the introduction of CDO. Such a report will facilitate dialogue with the community and the regulating authorities. It will also produce useful information for any future considerations of CDO implementation.

Part B

IMPLEMENTATION GUIDANCE

Chapter 1

INTRODUCTION TO IMPLEMENTATION PROCESSES

1.1 IMPLEMENTATION STEPS

The following steps provide a map to CDO implementation. The degree of effort or time spent on each step will depend on a number of local factors, including the degree to which operational collaboration between all stakeholders is already established. The process is based on the classic plan-do-check-act philosophy and is comprised of four main CDO implementation phases.

1.1.1 Initial proposal to consider CDO

1.1.1.1 The initiation of CDO implementation may be proposed by any operational stakeholder. The individual proposing CDO is hereinafter referred to as the “Initiator”.

1.1.1.2 It may not be possible for the initiator to undertake a full preliminary CDO viability assessment at this stage; however the following policy context and considerations may provide justification:

- a) national or local regulatory guidance;
- b) airport and/or airspace development plans;
- c) existing plans for CDO, if any;
- d) sources of guidance and practical support;
- e) generic potential benefits and risks; and
- f) optionally, an outline proposal for preliminary informal consultation processes.

1.1.1.3 In light of this informal review against the above points, the initiator should prepare a short preliminary report to secure interest from fellow operational stakeholders. It is important to engage all key operational stakeholders at an early stage using informal networks. This can be achieved very effectively through a dedicated CDO workshop, at local, regional and/or national level, designed to:

- a) reach a common understanding of the present operational situation at the airport(s) — and potential operational improvements;
- b) reach a common understanding on CDO-related opportunities, benefits, gaps, issues and risks from different operational perspectives;
- c) jointly decide if CDO is considered viable enough to continue with the implementation process, and, if so;
- d) agree on an “in principle” way forward (i.e. the next few steps) based on this guidance; and

- e) nominate (initial) points of contact and define actions and associated timelines arising from the workshop.

1.1.1.4 The typical participants at such a workshop could include the following:

- a) representatives of the aircraft operators, including:
 - 1) policy/decision maker;
 - 2) senior pilot(s); and
 - 3) technical support (including FMS expertise);
- b) representatives of the ANSP, including:
 - 1) policy/decision maker;
 - 2) management and controllers of affected ATC units;
 - 3) airspace designers; and
 - 4) procedure designers;
- c) representatives of the aerodrome operator, including:
 - 1) environment department; and
 - 2) operations department;
- d) optionally, the following participants:
 - 1) aviation regulator;
 - 2) Ministry of Transport;
 - 3) industry representatives;
 - 4) international organizations or agencies (where appropriate); and
 - 5) Ministry responsible for the environment.

1.2 PREPARE AN OUTLINE CDO CASE

1.2.1 A well constructed case for CDO will secure the essential top management commitment and hence allocation of resources to take CDO implementation forward. The outline case can be largely constructed from the workshop outcome in the previous implementation step. A model layout is as follows:

- a) outline description of the proposed CDO, its stimulus and the policy context;
- b) description of practical support available;
- c) outline estimation of potential benefits and costs (outline benefits are covered later in this manual);
- d) outline implementation road map including approvals required and go-no-go decision points and proposed working arrangements, including points of contact and proposed lead stakeholder¹ (including project leader if known);

1. If CDO is driven by noise abatement requirements, the lead stakeholder could be the organization with legal environmental accountability, which is often the aerodrome operator.

- e) top commitment requirements (what is expected from CDO policy/decision makers);
- f) recommendations; and
- g) annexes:
 - 1) description and outcomes from the workshop;
 - 2) potential CDO facilitation candidates;
 - 3) gaps and risks.

1.2.2 For CDO implementation to be successful, senior management commitment is essential from each stakeholder in order to give the work priority, drive progress and release the required resources. For some States, and especially where operational stakeholders are State authorities, a formal or legal agreement may be required to allow collaboration to take place. In some cases, approval from a State regulating authority may be required to allow the CDO implementation to progress past a certain point.

1.3 ESTABLISH A CDO COLLABORATIVE IMPLEMENTATION GROUP

1.3.1 Once top management commitment is confirmed, the informal consultation arrangements and agreed points of contact should be consolidated into a formal working arrangement.

1.3.2 Early tasks will include the following:

- a) ensuring a common understanding of the work undertaken so far;
 - b) agreement on terms of reference (TOR) (model TOR are provided in Appendix 1);
 - c) identification of skill requirements, co-opting members and/or informing supporters of potential support requirements accordingly;
 - d) agreement on the initial roadmap — the roadmap in this guidance may be used — but with more detail on the planning phase;
 - e) agreement on roles and responsibilities; and
 - f) establishment of consultation and reporting processes.
-

Chapter 2

PLANNING

2.1 JOINT PRELIMINARY ASSESSMENT

2.1.1 A robust joint preliminary assessment of CDO will ensure that subsequent CDO implementation steps are based on robust foundations. The overall aim is to jointly determine whether CDO is likely to be viable.

2.1.2 This will require joint consideration of:

- a) what is the base case²;
- b) what performance changes, i.e. positive or negative, could arise from CDO;
- c) what direct and indirect barriers, risks and enablers exist (at a high level); and
- d) what CDO facilitation alternatives and combinations should be considered.

2.1.3 The scope for the preliminary assessment should be wide-ranging but outlined in depth and should consider fundamental issues such as:

- a) where do aircraft fly in relation to population centres;
- b) how do arrivals and departures interact;
- c) by using data from, for example, track monitoring systems, radar/flight data recordings, what are the present vertical arrival/approach and departure profiles, and how much level flight is there on arrival/approach and departure;
- d) how much CDO occurs at present;
- e) what relevant plans or developments are underway within the airspace and at the airport;
- f) what are the relevant regulations and policies, for example, consultation requirements;
- g) what capabilities will be needed, in terms of, for example, ATC and flight simulation, monitoring and feedback loops;
- h) what related effects may exist, for example, effects on capacity or departure profiles;

2. The base case may be the present pre-CDO case, but if CDO is part of a wider operational change or infrastructure development, the base case may be the future “do nothing” or “no-CDO” case, in accordance with planning horizon time frames.

- i) what risks exist and what mitigation is required, for example, how may traffic growth affect the ability to perform CDO;
- j) how might consultation obligations delay CDO implementation;
- k) what change to noise impact may occur, for example, a change to geographical locations of noise impact, concentration or dispersion of noise impact; and
- l) what quick-win opportunities exist, for example, rapid implementation of tactical CDO in very low traffic scenarios.

2.2 CONSIDER OPTIONS AND JOINTLY AGREE ON PREFERRED IMPLEMENTATION

2.2.1 It is essential to consider all of the options for facilitating CDO implementation as well as the scope of any CDO procedure, e.g. start point/level and end point/level. This is especially important if the assessment method is governed by environmental impact assessment legislation, requiring that alternatives be considered.

2.2.2 These alternatives could include:

- a) CDO facilitation methods described previously in this document;
- b) phased introduction during low traffic periods;
- c) phased introduction during heavier traffic density levels with automation support or other facilitation;
- d) single or combined facilitation methods;
- e) combining RNAV routes in the earlier arrival/approach phases where sequencing may be less complex with vectoring at lower altitudes;
- f) combining procedural and vectoring techniques such as merge point where an RNAV fixed route approach is provided with the intention of offering a "Direct To" instruction to vector aircraft from the route, towards a fixed "merge point";
- g) initiating CDO from different levels during different traffic density levels; and
- h) initiating CDO from TOD in less busy periods.

2.3 DESIGN PREFERRED CDO FACILITATION OPTION(S)

2.3.1 At this stage, a final CDO implementation solution will have been described, with adequate reasoning to explain how and why this was selected.

2.3.2 This preferred option now needs to be designed, and this will require the following actions:

- a) review applicable rules and guidance material to provide assurance that the solution is compliant;

- b) determine if airspace changes are required;
- c) decide on procedure design to be implemented;
- d) identify required changes to manuals, procedures, letters of agreement and other relevant documentation used by aircraft operators and service providers;
- e) identify prerequisite technical enablers required to be delivered in time for implementation to commence, e.g. navigation requirements and aids, updating of software for airborne and ground-based systems;
- f) determine training requirements; and
- g) update the initial safety assessment.

2.4 STRATEGIC PLANNING

2.4.1 It is important that all stakeholders agree to and support the Strategic Plan for implementation of the selected CDO solution.

2.4.2 A joint agreement document covering the following issues will be required:

- a) basic project management;
- b) phases of continuing CDO development (list small steps towards longer term vision);
- c) critical path activities and their management;
- d) individual roles and responsibilities;
- e) reporting structures both for project management and CDO implementation assessment purposes;
- f) CDO implementation success rate, e.g. percentage of CDO achieved and/or amounts of fuel saved and emissions reduced;
- g) safety requirements for the operational trial to ensure that simulation and validation testing result in a safe operational trial; and
- h) risk management assessment.

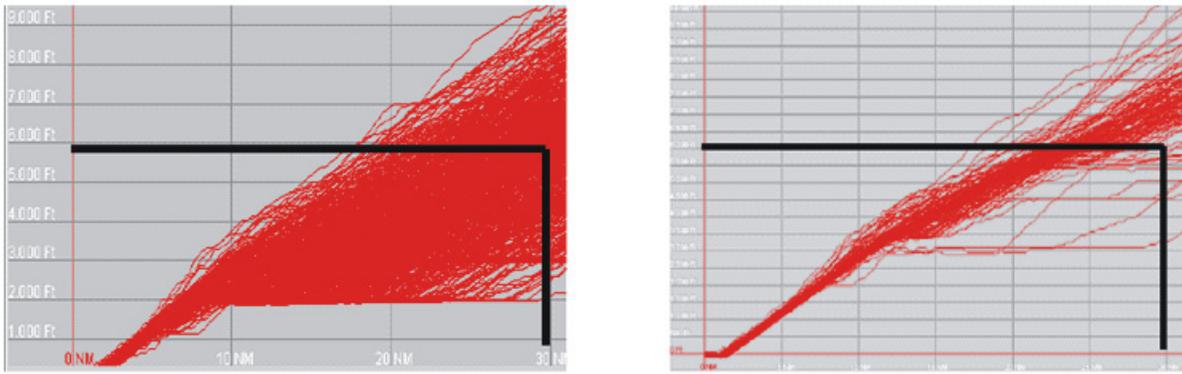


Figure 2-1. Comparison of actual aircraft profiles with and without CD Operations

Chapter 3

IMPLEMENTATION

3.1 SIMULATE AND VALIDATE

3.1.1 At this stage of the process more detailed flight and ATC simulation is necessary. This activity should include participation by those individuals who will be involved in implementing and taking part in any trial. This will help to double-check the viability of the selected solution and to foster acceptance and understanding before flight trials commence.

3.1.2 The initial safety assessment should be rechecked and updated if necessary with the aim of allowing an operational flight trial. This may require endorsement by the aviation regulator. Assuming that the preferred option is validated, the strategic plan should be jointly upgraded to an implementation plan, including specific accountabilities, general communications processes, training, dealing with unplanned events or variance from the plan and rapid reporting of safety issues. The trial plan and its implementation should be jointly agreed as fail-safe prior to initiation of CDO.

3.1.3 *Human Factors considerations for CDO.* CDO is being implemented around the world as part of a transition to a performance-based navigation system. These procedures are providing significant benefits and have also caused some Human Factors issues to emerge. Issues include aspects of air traffic control, airline procedures, aircraft systems and procedure design. There is a need for specific instrument procedure design guidelines that consider the effects of human performance. The following paper, produced by NASA, discusses Human Factors issues and proposes areas for further consideration.

“Human factors consideration for area navigation departure and arrival procedures” by Richard Barhydt and Catherine A. Adams, NASA Langley Research Center.

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20060048293_2006250467.pdf

3.2 DECISION POINT (GO-NO-GO)

Based on the outcome of the simulation and validation activities and provided that the safety assessment shows that all identified hazards have been managed to an acceptable level of risk, the plans to proceed should be endorsed by senior management at this point.

3.3 MAKE CDO OPERATIONAL AND IMPLEMENT ITERATIVE IMPROVEMENTS

3.3.1 The collaborative group should meet to ensure that everyone involved understands the overall intentions and operation of the trial and their role in it.

3.3.2 The trial may be implemented initially on a limited basis, e.g. for a single runway, in low traffic density levels and with a limited number of aircraft operators, or only the lead carrier where this is relevant. Alternatively, methods and procedures may be developed to implement the trial on a tactical basis. For both types of implementation

approaches, defined ATC procedures for the integration of aircraft not participating in the CDO trial need to be established.

3.3.3 Performance monitoring will be important and there will be a need to correlate:

- a) the extent to which and how a CDO was offered and/or followed;
- b) aircraft identification;
- c) flight performance information; and
- d) reasons for non-compliance, if any.

3.3.4 All parties involved in the CDO trial need to be informed of the decision to proceed and given access to the trial plan. This plan will include delegated accountability for assuring the readiness of controllers and pilots, including training activities, to proceed to the operational trial.

Assessment

3.3.5 Assessment of performance should be based on the progress results of the trial and should cover the key performance areas of most relevance for local circumstances.

3.3.6 These should include the following:

- a) updating of the safety assessment and needs;
- b) cost-effectiveness, in particular, aircraft fuel savings;
- c) workload impact on flight crews and controllers;
- d) environment impacts, including noise and emissions;
- e) effect on capacity;
- f) effect on training requirements; and
- g) feedback to participants.

3.3.7 It will be essential to define the parameters by which to assess CDO participation and performance. The parameters should have sufficient flexibility to achieve a good balance between CDO achievement in terms of numbers of compliant flights and individual CDO performance.

Training and awareness material

3.3.8 To support full CDO implementation, local guidance and awareness material should be produced and promulgated in addition to the formal publication of the CDO.

3.3.9 The supporting training and awareness material could include:

- a) CDO benefits and their local importance;

- b) training requirements for the selected (open or closed) CDO facilitation method;
- c) a simple pamphlet describing the aims and requirements for CDO;
- d) the individual roles and responsibilities relevant to the conduct of individual CDO flights; and
- e) method for providing ongoing feedback on progress to all participants.

3.3.10 Building on the previous two-way consultation process, the local community should also be informed of the intention to proceed from trial to a full implementation of CDO. Processes for ongoing community engagement and information should be developed.

3.4 FULL IMPLEMENTATION

3.4.1 Following a successful outcome of the trials, full implementation of CDO should be progressed through established channels.

3.4.2 The following issues should be considered:

- a) statutory consultation obligations;
 - b) the timing of the start-up period, to include publication cycles; and
 - c) performance monitoring and review.
-

Chapter 4

REVIEW

4.1 FEEDBACK TO AND CONSULTATION BETWEEN PARTICIPANTS

4.1.1 Regular feedback on CDO performance to all involved operational stakeholders is critical to the successful implementation and continued application of CDO. Equally critical is offering those involved with CDO a “just-culture” reporting channel for reporting safety concerns and proposing improvements. Any reported safety concern should be addressed as a matter of priority. It is also essential to address specific improvements identified by the more formal review of specific issues that arise as part of performance monitoring.

4.1.2 It is also important to inform the community of ongoing progress and to seek their opinion and perceptions on the effects of CDO through established channels.

4.2 CONTINUOUS REVIEW AND PLANNING OF CDO IMPROVEMENTS

The CDO collaborative working arrangement, e.g. the CDO Implementation Group, should also assume an ongoing responsibility for the following:

- a) review of CDO implementation progress and performance;
- b) monitoring of external developments in technology and practice;
- c) review of potential local changes, e.g. airspace changes or implementation of new controller tools, that may present opportunities or risks to CDO performance; and
- d) implementation of improvements.

Appendix 1

SPECIMEN TERMS OF REFERENCE

CDO COLLABORATIVE IMPLEMENTATION GROUP (CG)

1. All members maintain an up-to-date knowledge of the following:
 - a) the organizations that are participating;
 - b) their own organization's role and responsibilities;
 - c) the roles and responsibilities of other participants; and
 - d) the status of the CDO procedure (e.g. its definition and scope and when and how it is to be applied).
2. The CDO implementation plan is prepared and designed to fulfil the CG terms of reference.
3. CDO facilitation is designed in accordance with the criteria detailed in the PANS-OPS (Doc 8168), Volume II.
4. Once draft procedures have been produced, an "Interim CDO Assessment" is undertaken covering safety, capacity and workload issues.
5. Following a successful "Interim CDO Assessment" and adequate training of approach controllers and participating pilots, the provisional procedures are implemented as a limited trial.
6. Following a successful trial, CDO use is introduced or expanded according to a plan developed by the stakeholders and approved by the appropriate authority.
7. Adequate local guidance, training and promotional activities and materials are developed and applied to maximize the achievement of CDO. This is combined with regular feedback and reporting on CDO compliance.
8. Once the CDO procedure has been introduced, a continuous review of progress is established in order to identify opportunities to improve performance, including suggestions from operational staff. Open reporting on safety concerns is encouraged amongst all members.

CDO IMPLEMENTATION GROUP (CIG) SPECIMEN TERMS OF REFERENCE

9. The CIG is comprised of senior representatives from the aerodrome operator, ANSP, aircraft operator(s) and appropriate State authorities. (If an existing body already exists where the required stakeholders are present, then the duties set out below can be formally included in the existing terms of reference for that body.)

10. All members maintain an up-to-date knowledge of the following:
 - a) the organizations that are participating;
 - b) their own organization's role and responsibilities;
 - c) the roles and responsibilities of other participants; and
 - d) the status of the CDO procedure (e.g. its definition and scope and when and how it is to be applied).
 11. A CDO implementation plan is prepared in accordance with conditions established by the CG.
 12. Once draft procedures have been produced, an "Interim Assessment" is undertaken covering safety, capacity and workload issues. A separate Hazard Analysis is completed prior to the start of the trial.
 13. Following a successful "Interim Assessment" and adequate training of approach controllers and participating pilots from the lead or nominated carrier(s), the provisional procedures are implemented as a limited trial.
 14. Once the trial is commenced, a continuous review of progress is undertaken in order to identify opportunities to improve performance, taking into account suggestions from operational staff. Open reporting is encouraged amongst all members, and appropriate feedback arrangements are implemented to identify those flights in which a CDO was commenced but terminated or modified.
 15. Following a successful trial, CDO is introduced according to a defined plan.
 16. Adequate local guidance, training and promotional activities and materials are developed and applied to maximize the achievement of CDO. This material will be updated, as necessary, as a result of further feedback and reporting on CDO compliance.
-

Appendix 2

CDO PHRASEOLOGY EXAMPLES

Note 1.— Phraseologies and associated procedures described in this Appendix are used by at least one State as a means of accomplishing CDO.

Note 2.— The need for clear, concise and unambiguous phraseologies in controller-pilot communications applies equally to CDO. ICAO is currently analysing proposals addressing concerns which have been identified related to the PANS-ATM SID/STAR provisions. It is intended that any new provisions would take into consideration CDO.

1. A “descend at pilots discretion” or “descend when ready” clearance will not be given earlier than necessary but should ideally be given as close as possible to a distance from touchdown from where an optimized CD will naturally result (and hence the least track miles). The phraseology “descend at pilots discretion” or “descend when ready” provides options and therefore flexibility to the operation.

PHRASEOLOGY

DESCEND AT PILOTS DISCRETION *or* DESCEND WHEN READY

EXAMPLES-

“Two-five miles to fly, descend at pilots discretion.”

“Cross BUDDE at level 120, then descend when ready”.

2. 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.

2.1 A “descend via” differs from a “descend at pilots discretion”, because a “descend via” has vertical and lateral navigation, altitudes and speeds to be complied with, whereas a “descend at pilots discretion” has no boundaries that are defined in the procedure. Therefore the “descend via” profile is known in advance to ATC and pilots, adding predictability to the procedure.

“Descend via” instructions to vertically navigate on a STAR with published restrictions.

PHRASEOLOGY

DESCEND VIA (*designator*)

EXAMPLES-

“Descend via KODAP1A.”

“Cross ABC intersection at flight level two four zero, then descend via COAST TWO Arrival.”

TERMINAL: “Descend via the RIIVR TWO Arrival, after RIIVR, cleared ILS runway two five left”

Note 1.— Clearance to “descend via” authorizes pilots:

a) *to vertically and laterally navigate on a STAR; and*

- b) *when cleared to a waypoint depicted on an instrument flight procedure, to descend from a previously assigned altitude at “pilot’s discretion” to the altitude depicted for that waypoint, and once established on the depicted arrival, to navigate laterally and vertically to meet all published restrictions.*

Note 2.— ATC is responsible for obstacle clearance when issuing a “descend via” clearance from a previously assigned level.

Note 3.— Pilots navigating on an instrument approach or arrival procedure shall maintain last assigned level until receiving clearance to “descend via”.

Note 4.— Pilots cleared for vertical navigation using the phraseology “descend via” shall inform ATC upon initial contact.

EXAMPLE: “Delta One Two One leaving FL 240, descending via the KODAP2 arrival.”

Attachment A

TAILORED ARRIVALS

1. Tailored arrivals (TA) are being trialled in some States. This Attachment contains an example of a potentially beneficial CDO using data link communications.
2. Tailored Arrivals are projected to be a “high end” automated application capturing all the benefits of CDO as outlined in Chapter 1, “Description of Continuous Descent Operations”, 1.1.
3. The ideal TA is a trajectory that allows the aircraft to meet the required time at the metering fix (if any) while performing an idle descent along the optimal lateral path. However, the desire for operational economy and reduced environmental impact must be tempered with practicality that emanates from several sources. Safety must be assured by avoidance of severe weather, terrain and other traffic, and by conformance with variable airspace availability. In addition, airport and runway capacity must be maintained by precise, predictable sequencing and by coordination of arrival and departure streams.
4. The TA clearance is calculated by the ground system to provide the controller with a means of delivering the aircraft at its required time over a downstream fix while simultaneously satisfying all other ATC needs. The cleared lateral path and other constraints are communicated by data link to individual flights prior to TOD as part of the arrival clearance for use by the flight management computer (FMC) in calculation of the descent path. Updated meteorological information is also provided to improve flight path efficiency and to allow more precise path calculation and timing predictability. The clearance may include speed and altitude constraints and lateral length adjustment to increase control authority for sequencing and coordination.
5. The resulting arrival is tailored to provide the most efficient flight path in the existing conditions and will almost always be more efficient than that achieved with traditional tactical vectoring techniques.
6. Figure ATT A-1 illustrates the TA concept, with speed control used to adjust the timing and descent profile of the aircraft entering from the right.
7. The full TA concept addresses inefficiencies in current operations by combined use of ground-based automation and the aircraft’s on-board capabilities. Based on traffic and weather likely to be encountered during the descent, ATC calculates a complete descent clearance from TOD to landing, coordinates it across all sectors from cruise to landing, and then uplinks it via controller-pilot data link communications prior to the aircraft’s TOD. The clearance includes any speed and altitude requirements and any path adjustments required to tailor the arrival, as well as a published approach for the final segment. Based on the clearance, the FMS/FMC calculates an optimal descent profile. The key is the completeness of the clearance delivery to the flight deck before the descent starts, as this enables the aeroplane’s automation to perform its calculations, providing most predictability for ATC, fuel savings for the airlines, and noise and emissions reductions for surrounding communities.
8. There are a number of important enablers for implementation of the TA concept. Most of these enablers are mature technology available for activation on current production aircraft and for implementation in today’s ATC systems. However, two important enablers are still in the developmental stage that is critical to full implementation. These are:

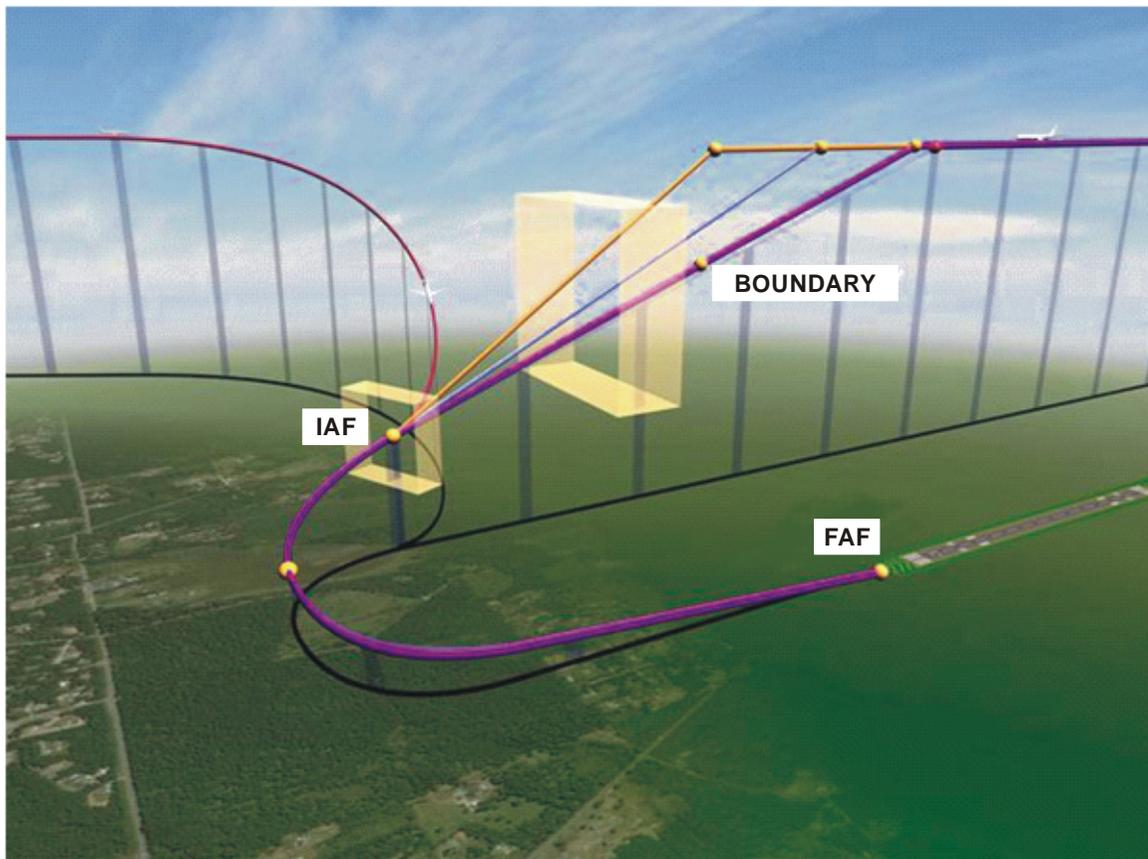


Figure ATT A-1. The TA concept

- a) ATC capability to coordinate clearances that span an aircraft's entire descent path, across multiple ATC centres and sectors; and
- b) ground decision support tools capable of providing fuel-efficient descent solutions in the presence of complex traffic constraints and airspace restrictions.

8.1 Figure ATT A-2 illustrates the primary system components required for TA, highlighting two key enablers.

8.2 These two key enablers have driven the definition of two variations of TAs:

Initial Tailored Arrivals, which lack the two enablers and have the following primary features:

- a) new inter-centre coordination techniques to support coordination and delivery of a clearance from TOD to the runway, however this does not incorporate new ground decision support tools; and
- b) reduced benefit; because of the lack of ground automation, a smaller proportion of flights are able to complete the full TA to the runway, resulting in lower benefits than the automation-supported TA.

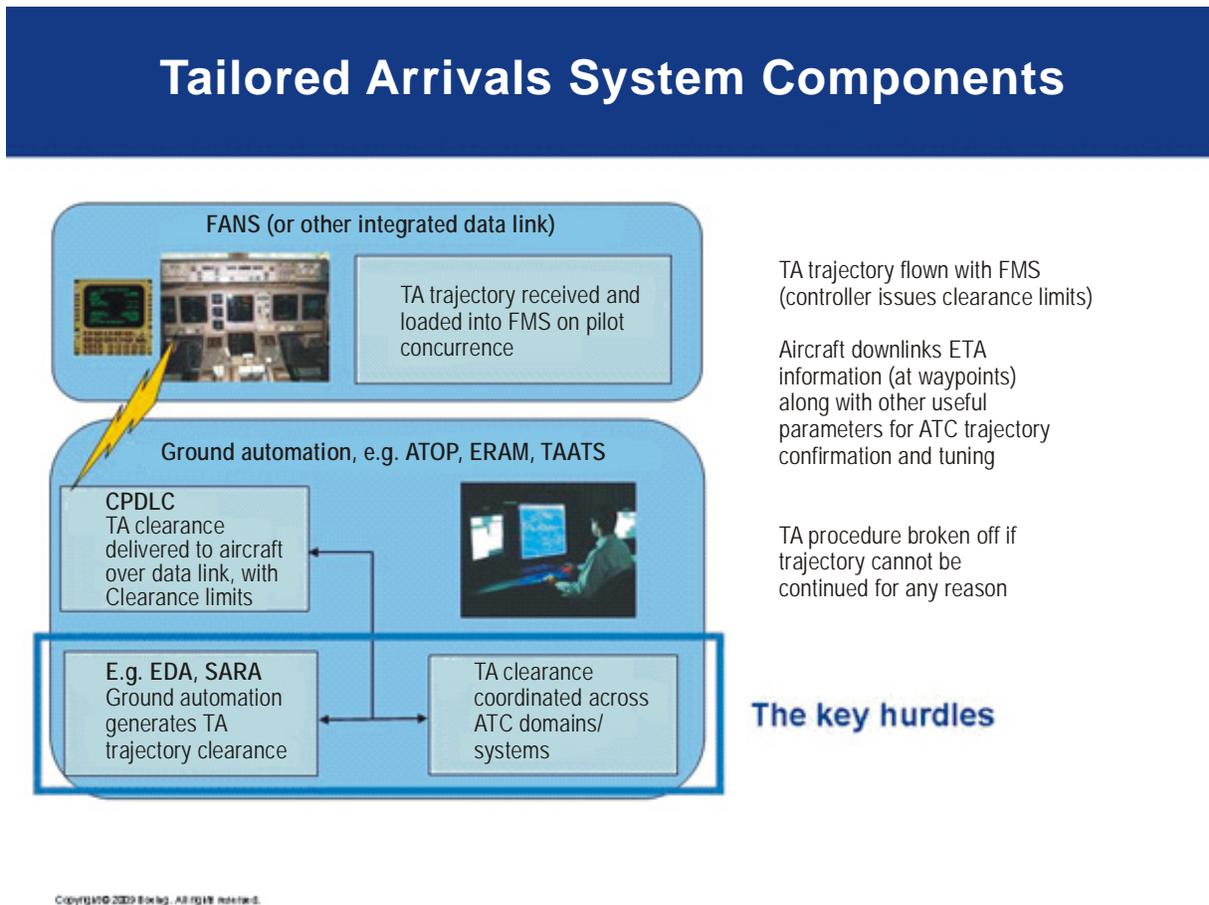


Figure ATT A-2. Tailored Arrivals — Enablers

Automation-supported Tailored Arrivals, which have the following primary features:

- a) secondary enabler: new inter-centre coordination techniques and agreements to support coordination and delivery of a clearance from TOD to runway. Additionally, new ground decision support tools capable of providing fuel-efficient descent clearances from TOD to the runway are available; and
- b) high benefit; due to the availability of the ground automation, a large proportion of TAs are completed to the runway.

9. Figure ATT A-3 illustrates the functions provided by TA decision support tool automation.

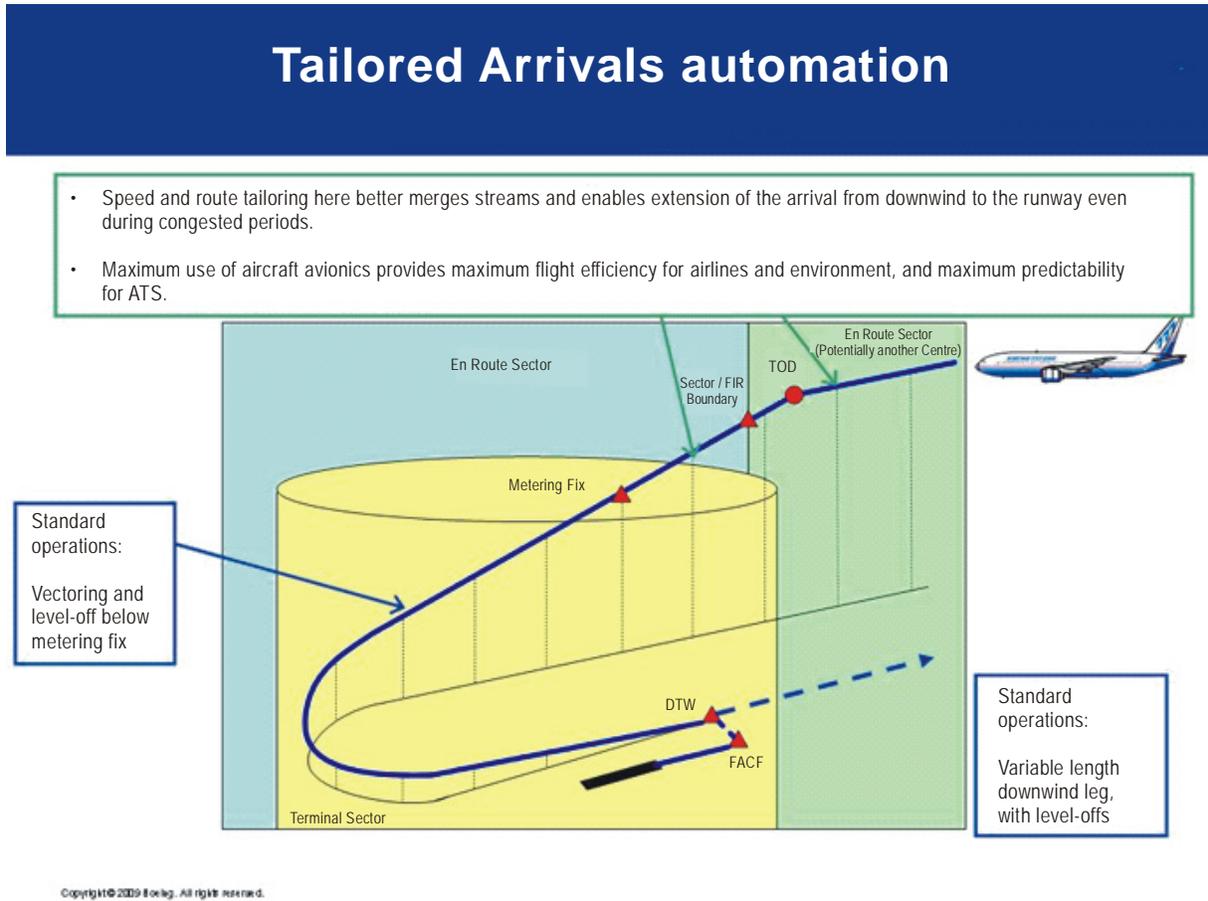


Figure ATT A-3. Tailored Arrivals — Variations

Attachment B

FLIGHT MANAGEMENT SYSTEM (FMS) VARIABILITY AND THE EFFECTS ON FLIGHT CREW PROCEDURE

1. The variability in operation and performance of existing aeroplane Flight Management Systems (FMSs) is well known but not necessarily well understood, documented or accommodated with respect to airspace design methodology. Subsequently, flight crews perform a wide range of procedural and “technique” methods to ensure that the FMS guidance, both laterally and vertically, complies with a published procedure.

2. With respect to variability in FMS operation, the most sophisticated FMSs are well integrated into the aeroplane’s “system of systems” and provide precise guidance to the lateral and vertical flight plan. Additionally, such FMSs contain aeroplane performance databases specific to the respective aero model. Subsequently, these FMSs, when coupled to the aeroplane’s flight control system, are capable of providing the flight crew with precise trajectory path management in a fashion that may reduce flight crew workload to the level of monitor as opposed to constant manager. Other less capable or integrated FMSs provide a range of capability and therefore require the flight crew to be more involved in path management. For example, some FMSs require that the flight crew specifically command the aeroplane to begin the descent. Other FMS models cannot couple to the aeroplane’s flight control system and require the flight crew to control the aeroplane’s trajectory via other modes. Still other FMSs may not have a vertical component at all, and the flight crew performs the descent and complies with constraints based upon “basic airmanship”. Although the equipage variability is slowly improving as older aeroplanes are retired, it is certain that many of those older aeroplanes will be operationally viable for several years to come.

3. Regardless of FMS capability or integration, the flight crew is obviously still required to ensure the aeroplane complies with the published flight plan path. Aviation industry research has revealed that the frequency of flight crew error is related to the complexity and variability of automation in the flight deck. Another significant factor affecting crew error is the complexity of the airspace. As the airspace becomes increasingly dense, procedure designers have used various design techniques to accommodate traffic, terrain and environmental constraints. That has resulted in additional complexity with which the flight crew must cope using the available on-board tools. Unfortunately, some of those procedures have unknowingly “set up” the flight crew for error because of unaccommodating FMS operation. As a result, discussions and working group activity are ongoing within the industry on procedure design and how those designs should be cognizant of FMS capability. Given the future implementation of NextGen and SESAR and tools like the CDO and TAs, future airspace and procedure designers should carefully ensure that their designs consider the airspace requirements, capability of the FMS, and the resulting workload on the flight crew. A “working together” approach would be very beneficial for designers.

— END —

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