Doc 9993
AN/495

Continuous **Climb** Operations (C**C**O) Manual

Approved by the Secretary General
and published under his authority

First Edition — 2013

International Civil Aviation Organization

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AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

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FOREWORD

The purpose of this manual is to provide guidance on continuous climb operations (CCO) and to harmonize its development and implementation. The climb phase uses a significant proportion of the total flight fuel; introducing efficiencies in this phase could provide significant economic and environmental benefits in terms of both noise and emissions.

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 facilitate the ability of flight crews to use in-flight techniques to optimize the efficiency of the climb operation through a coherently developed airspace concept. This will be achieved while maintaining air traffic management (ATM) capacity and, as a result of the design taking into account actual ranges of flight profiles, remove or at least reduce the potential for conflict between traffic flows thereby increasing safety.

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

a) air navigation service providers (ANSP), including;

   1) policy/decision makers;
   2) airspace designers;
   3) instrument procedure designers; and
   4) operational ATC staff;

b) aircraft operators:

   1) policy/decision makers;
   2) pilots; and
   3) technical (flight management system (FMS) expertise) staff;

c) airport operators including:

   1) operations department; and
   2) environment department;

d) aviation regulators.

The CCO manual forms one part of a package of related documents where the overarching document is the *Manual on the Use of Performance-based Navigation (PBN) in Airspace Design* (Doc 9992) with the Continuous Climb Operations (CCO) and Continuous Descent Operations (CDO) manuals forming examples of the application of the airspace concept.

Future developments

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

The Secretary General
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999 University Street
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EXECUTIVE SUMMARY

Continuous climb operations (CCO) is an aircraft operating technique enabled by airspace design, instrument procedure design and facilitation by ATC, allowing for the execution of a flight profile optimized to the performance of the aircraft. CCO enables the aircraft to attain initial cruise flight level at optimum airspeed and engine thrust settings set throughout the climb, thereby reducing total fuel burn and emissions. Ideally, the departure design is such that arriving traffic is also able to descend based on an optimum descent profile. Where the departure and arrival flows cannot be designed independently, there will need to be a compromise between the needs of the departure and arrival flow optimization; this compromise should be reached collaboratively.

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

a) air navigation service providers, including both terminal and en-route facilities;

b) aircraft operators/pilots;

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 efficient climb profiles, minimizing interference between departing and arriving traffic;

b) understanding of requirements for continuous climb profiles; and

c) understanding and harmonization of associated terminology.

CCO is one of several tools available to aircraft operators and ANSPs that, through collaboration between stakeholders, will make it possible to increase efficiency, flight predictability and airspace capacity, while reducing fuel burn, emissions and controller-pilot communications, thereby maintaining safety. Over the years, different airspace models have been developed to facilitate efficient terminal operations, and several methods have been adopted to optimize the terminal airspace design to provide a balanced approach towards achieving profiles close to the ideal fuel-efficient and environmentally friendly procedures, while maximizing the capacity of an airport and its surrounding airspace.

Starting with the design of the standard instrument departure (SID), an optimum continuous climb can be undertaken from take-off to cruise, including the noise abatement departure procedure, reducing both controller-pilot communications and segments of level flight. Such a profile should also provide a reduction in noise, fuel burn and emissions, while increasing flight stability and the predictability of the flight path to both controllers and flight crews.

Standard instrument departure/standard instrument arrival (SID/STAR) procedures should be designed in concert with one another to achieve balanced flight path profiles thereby ensuring that the profiles meet the needs of both the ATC and operators to the greatest extent possible. The procedures need to be presented in an unambiguous manner, ensuring the ATC and flight crews have a common understanding of requirements and the resulting flight profiles. To achieve this, the instrument procedure designer needs to understand the flight characteristics, limitations and capabilities of the range of aircraft expected to perform CCO at the subject airport, as well as the characteristics of the airspace and routes where CCO 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 when proposing CCO.

The climb is the phase of operations that uses the highest rate of fuel during a flight. Considering the growing concerns about the environment and particularly climate change and taking into account the high cost of fuel, collaborating to facilitate CCO is essential for all operational 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 CCO-based procedure 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 climb 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)

Circular 317*, Effect of PANS-OPS Noise Abatement Departure Procedures on Noise and Gaseous Emissions*

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-() Navigation System Database Specification

Document number changes

The bundling of Federal Aviation Administration (FAA) Advisory Circulars (ACs) or European Aviation Safety Agency (EASA) Acceptable Means of Compliance (AMCs) may result in document number changes, e.g. AC 20-138B supersedes AC 20-129/AC 20-130A/AC 20-138A/AC 25-4). Similarly, some technical standard orders (TSOs) have been superseded by newer publications, e.g. FAA TSO-C129() superseded by TSO-C196. In these cases, the original document number available at the time of issue has been retained.

ACRONYMS

ADS-B	Automatic dependent surveillance — Broadcast
ANSP	Air navigation service provider
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic services
CCO	Continuous climb operations
CDO	Continuous descent operations
EUROCAE	European Organisation for Civil Aviation Equipment
FMC	Flight management computer
FTS	Fast time simulation
FMS	Flight management system
ICAO	International Civil Aviation Organization
LNAV	Lateral navigation
MSL	Mean sea level
NADP	Noise abatement departure procedure
NADP 1	Noise abatement departure procedure 1 — an example noise abatement procedure given in ICAO Doc 8168
NADP 2	Noise abatement departure procedure 2 — an example noise abatement procedure given in ICAO Doc 8168
NM	Nautical mile
PBN	Performance-based navigation
PSR	Primary surveillance radar
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RF	Radius to fix
RTS	Real time simulation
SID	Standard instrument departure
SSR	Secondary surveillance radar
STAR	Standard instrument arrival
TA	Transition altitude
TF	Track to fix
TL	Transition level
TOC	Top of climb
TOR	Terms of reference
VM	Heading to manual termination
VNAV	Vertical navigation

EXPLANATION OF TERMS

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.

Continuous Climb Operation (CCO). An operation, enabled by airspace design, procedure design and ATC , in which a departing aircraft climbs without interruption, to the greatest possible extent, by employing optimum climb engine thrust, at climb speeds until reaching the cruise flight level.

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 en-route or arrival phase of flight will achieve the maximum reduction in fuel burn, noise and emissions.

Level. A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level.

Mixed navigation environment. An environment where different navigation specifications may be applied within the same airspace (e.g. RNAV 1 routes and conventional navigation operations in the same airspace) or where operations using conventional navigation are allowed in the same airspace with RNAV or RNP applications.

Noise Abatement Departure Procedure 1 (NADP 1). An example departure procedure alleviating noise close to airport (see PANS-OPS (Doc 8168), Volume I).

Noise Abatement Departure Procedure 2 (NADP 2). An example departure procedure alleviating noise distant from the airport (see PANS-OPS (Doc 8168), Volume I).

Navigation aid (navaid) infrastructure. Space-based and/or ground-based navigation aids available to meet the requirements of 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 on-board 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 PBN Manual (Doc 9613).

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. Air traffic control service provided by using information derived from sources other than an ATS surveillance system.

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. An RNP system may be included as part of a flight management system (FMS).

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 instrument flight rule (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 CLIMB OPERATIONS OVERVIEW

Chapter 1

DESCRIPTION OF CONTINUOUS CLIMB OPERATIONS

1.1 INTRODUCTION

1.1.1 Continuous climb operations (CCO)

1.1.1.1 An aircraft's fuel efficiency in terms of fuel burned per kilometre flown in level flight increases with height. However, the fuel used in climbing to that altitude can be a significant part of the overall fuel used for the flight. Therefore, for any given route length, there is an optimum initial cruise flight level which will be dependent upon the aircraft type and mass, as well as on the meteorological conditions of the day. CCO is only one of the tools involved in a complete airspace design. Throughout the design process, CDO, CCO and other route modifications should all be considered.

1.1.1.2 CCO is an aircraft operating technique made possible by appropriate airspace and instrument procedure design and appropriate ATC clearances enabling the execution of a flight profile optimized to the performance of the aircraft, thereby reducing total fuel burn and emissions during the whole flight.

1.1.1.3 The optimum vertical profile takes the form of a continuously climbing path. Any non-optimal climb rate segments during the climb (other than during the noise abatement departure procedure (NADP)) to meet aircraft segregation requirements should be avoided. However, achieving optimal vertical profiles, while also enabling continuous descent operations (CDO) and maximizing the overall airport capacity, is critically dependent upon the airspace design and the level windows applied in the instrument flight procedure or ATC clearances. Such airspace designs need to take into account the optimum profiles for aircraft operating at the airport to ensure that the instrument procedure designs balance the need to avoid level and speed constraints that prevent efficient climb profiles with other aircraft operations in the airspace. Appropriate airspace design should be used to avoid, to the greatest extent possible, the need to resolve potential conflicts between the arriving and departing traffic flows through ATC level or speed constraints.

1.1.1.4 There is a difference in design philosophy between CCO and CDO. In surveillance environments, the CCO design should take into account that tactical changes to the flight path, initiated by ATC, may be desirable. In general, CDO aircraft should be left on the designed route and not given a vector "shortcut" because a CDO aircraft is already descending at flight idle power and thus descending at the steeper angle a shortcut requires may lead to an unstable approach. In contrast, ATC tactical shortcutting of a CCO departure to take advantage of observed aircraft climb performance is desirable because it saves both flight mileage and time. The potential for tactical shortcutting should be considered in any CCO design, as well as the fact that other flow restrictions potentially restrict the opportunity of ATC to provide tactical shortcuts. Section 1.3.2 provides several examples of designs that take advantage of tactical shortcutting by ATC.

1.1.1.5 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".

1.1.2 Facilitating continuous climb operations

1.1.2.1 Air traffic controllers are required to provide safe and efficient management of departing and arriving aircraft. However, the term “efficiency” can mean different things to different stakeholders and may vary depending on traffic density levels, the aircraft mix, atmospheric or weather conditions, and other local parameters. To achieve overall arrival and departure efficiency, a balance should be reached 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 departure profile should be used wherever and whenever possible, however the need to minimize noise impact may also provide conflicting imperatives. The weighing of the significance of aircraft noise imperatives is typically a national or local issue. The flight crew should however have the maximum flexibility to manage the aircraft’s speed and rate of climb or descent to achieve the collaboratively designed local requirements.

1.1.2.2 Ideally, to maximize the benefit of a CCO, it should start at take-off and encompass the departure noise abatement procedures and noise preferred route requirements immediately following take-off and continue through to the initial cruise level. Treating the CCO in this holistic manner enables due account to be taken of the influence of the NADP on the trajectory and allows selection of the most effective departure routing to maximize the overall economic and environmental benefits. To enable this course level, windows should be designed to take account of aircraft performance limits. Speed constraints may also need to be considered. All design constraints need to take account of the expected operations from the airport in all weather conditions, and any other important local data (e.g. obstacles, descent operations and the distribution of noise-affected population centres).

1.1.2.3 Such fully optimized departures to top of climb are not always possible due to the interaction of other traffic flows both into the same airport as well as flows into and out of other airports in the vicinity. However, while a fully optimal CCO may not be possible, a CCO carried out with appropriate ATC clearances and within the constraints of existing SID designs, even over shorter sections of the climb, can provide significant benefits.

1.1.2.4 The range of optimum climb profiles is normally much greater than descent profiles. Because of the need to cater for such a wide range of climb profiles while providing clearances to other flows of traffic in the terminal airspace, the designer may need to consider separating the heavy more slowly climbing traffic from the traffic wanting to climb at faster rates.

1.1.2.5 At some airports, it may not be possible to provide optimum climb and descent profiles that ensure segregation of arriving and departing traffic without ATC intervention in the form of speed control or vectoring to resolve conflicts between traffic flows. The increased availability of conflict prediction tools supported by accurate planned profile information from the aircraft will make such interventions rare even in high-density traffic. However, this need not prevent the application of CCO in the absence of such tools to provide the foundations of continual improvement. CCO facilitation methods should be selected and designed with the goal of balancing the use of CCO with CDO and other operations in the airspace, to achieve optimum airspace efficiency during the broadest periods of air traffic operations.

1.1.2.6 Designing and implementing CCO-based procedures includes the need for a decision on the preferred type of noise abatement departure procedure (e.g. NADP 1 or NADP 2 (see PANS-OPS (Doc 8168), Volume I)), as well as the lateral path followed by the procedures. This will necessitate the identification of areas affected by noise and identification of which type of (1 or 2) noise abatement procedure and departure route will provide the greater alleviation. As with some implementation scenarios for CDO, there may not be a noise reduction for all those affected. This may create the need for an effective public communication and decision process.

1.1.2.7 Where a trade-off between CCO and CDO is unavoidable, the local analysis and decision-making should take into account that a level segment for an aircraft in descent would normally burn less fuel than for the same duration of level segment for an equivalent aircraft in climb. But often there is far more unnecessary level flight in the descent phase than in the climb phase. The balance will depend on local characteristics such as the extent of level flight in both phases, the significance of noise in the areas affected, etc. ICAO and other international bodies are continually developing methodologies to assist such trade-off assessments, and where commonly agreed methods exist to assist in decisions, these should be used.

1.1.2.8 Level flight segments, where there are also speed constraints, result in much more severe operational constraints than where level flight segments occur where there is no speed constraint. This provides further incentive to avoid level flight segments where speed constraints exist.

1.1.3 Benefits

1.1.3.1 CCO offers the following advantages:

a) more fuel efficient operations;

b) reduction in both flight crew and controller workload through the design of procedures, requiring less ATC intervention;

c) reduction in the number of required radio transmissions;

d) cost savings and environmental benefits through reduced fuel burn and potential aircraft noise mitigation through thrust and height optimization;

e) potential authorization of operations where noise limitations would otherwise result in operations being curtailed or restricted.

1.1.3.2 Depending on the airspace concerned, the benefits of CCO will be optimized by a review of the airspace configuration for CCO, in order to provide, to the greatest extent possible, strategic separation of flows of traffic thereby enabling concurrent operations of CCO and CDO. As part of the airspace redesign and operation, the requirements for both strategic and tactical deconfliction measures need to take into account the profile envelopes expected to be followed by the range of aircraft expected to be served by a particular procedure at the airport under consideration.

1.1.3.3 If ATC were to lose the flexibility to optimize sequencing and management of departure and arrival flows, there could be a risk of reduced capacity and efficiency. CCO should be considered as being “the art of the possible” and, while highly desirable, it is not to be achieved at any cost. The achievement of CCO for one operation must be balanced with its effect on other operations.

1.1.3.4 In CDO with engines set in low thrust, noise from the airframe provides a significant contribution to the overall noise impact. Therefore, the focus for CDO is both on maintaining a clean configuration to the extent possible and minimizing unnecessary thrust. However, in a CCO, the aircraft is operating with high thrust settings and thus airframe noise is a less significant part of the overall noise produced. The focus for CCO should therefore be on optimizing thrust for noise where this is the overarching aim in the initial departure through the use of noise abatement departure procedures, and for fuel efficiency where noise is not significant following the noise abatement procedure, or, in airports where there is no noise-affected community. The significance of noise abatement and the extent to which it is applied are matters for local determination.

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 CCO-based procedures. Use of this guidance material should minimize the proliferation of definitions and concepts of operations and the resultant uniformity of operations should enhance safety by minimizing risk of misunderstanding of requirements by pilots and mistakes between ATC and flight crew. Additionally, standardization of procedures is expected in the form of amendments to the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS, Doc 8168). Updates to this manual are expected in light of future developments.

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 describes the intended operations within an airspace. Airspace concepts are developed to satisfy explicit strategic objectives such as improved safety, increased air traffic capacity and mitigation of environmental impact. Airspace concepts can include details of the practical organization of the airspace and its users based on particular CNS/ATM assumptions, e.g. ATS route structure, separation minima, route spacing and obstacle clearance."

1.1.4.2 CCO-based procedures can enable several specific strategic objectives and should therefore be considered for inclusion within any airspace concept or redesign. Guidance on PBN airspace concepts and strategic objectives is contained in Doc 9613, and supported by the *Manual on the Use of Performance-based Navigation (PBN) in Airspace* Design (Doc 9992). Objectives are usually collaboratively 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 and may require formal impact assessments. Such involvement may also be the case in the setting of the strategic objectives for 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. CCO-based instrument procedure design needs to take into account issues such as the flight paths of arriving aircraft, where uninterrupted descent 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 instrument 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 a CCO-based procedure, implementation time might be an important constraint as well as the phases of flight to which CCO is being initially applied. Additionally, limiting the changes to navigation requirements may reduce the implementation time frame.

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

1.1.4.7 Within the need to ensure that safety and capacity are not compromised, it may not always be possible to fly fully optimized CCO. The aim should be to optimize CCO to the extent possible, while not adversely affecting safety and/or capacity.

1.1.4.8 Implementation of future ATM tools for separation, sequencing and a phased implementation whereby CCO is implemented initially for only part of the departure, should further improve the early realization of benefits.

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 IAPs 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.

Environment: Requirements for reduced emissions, noise preferential routes or CDO/CCO are environmental motivators for change.

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.

1.1.5 Basic concepts of CCO

1.1.5.1 Reduced fuel burn

There are two main methods to minimize the amount of fuel burned during the take-off phase of flight:

a) continuous climb via the most optimum climb path, without intermediate level-offs; and

b) reducing the flight path distance of the departure procedure applied.

1.1.5.2 Continuous climb

1.1.5.2.1 Depending on route design, aircraft on both CCO and CDO may interact with each other requiring one or both aircraft to level off for a period of time in order to maintain separation. A balance must be sought between efficiencies gained by a CCO versus efficiencies gained by a CDO. An arriving aircraft conducting a CDO is performing an operation with low thrust settings (see Doc 9931). For similar types of aircraft, a level-off of a departing climbing aircraft in general will entail more fuel usage than the level-off of a similar arriving aircraft. Therefore, the application of both CDO and CCO must be considered during the design of an operational concept that comprises both arrival and departure phases of flight with the intent to balance overall efficiency.

1.1.5.2.2 The aircraft clean-up process, where lift and drag are balanced, is part of the applied departure procedure. Following the noise abatement procedure, the most optimum flight path of a departing aircraft is one with a continuous climb at optimum climb thrust and speed until the aircraft attains the cruise flight level.

1.1.5.2.3 The actual climb slope depends on many factors and could vary between zero per cent level flight (constrained) up to potentially more than 20 per cent (unconstrained for certain aircraft types and conditions) in different segments along the flight path.

1.1.5.2.4 The average aircraft climb gradient is influenced by the:

a) number of engines (two-engine aircraft climbing faster than three- or four-engine aircraft, when both engines are operating, as they have greater excess thrust to cause an engine-out condition);

b) aircraft weight;

c) wind direction and speed;

d) ambient temperature and pressure;

e) flap setting;

f) power setting;

g) aircraft type; and

h) aerodrome elevation.

1.1.5.2.5 The vertical profile is not a straight line climb rate, but is based on various segments, where actions such as gear and flap retraction, engine thrust cut-back and acceleration take place. During an intermediate levelling off, the aircraft will operate at a sub-optimum altitude and operational mode and will fly a longer track than necessary at non optimum altitude, consuming more fuel. At lower altitude, the aircraft may not be able to operate in a clean configuration (flap setting) during a level-off (depending on speed limitations). The higher air density at low level, added to the additional drag due to the extended flaps, typically requires additional energy. Levelling off at a higher intermediate altitude in a clean configuration is more efficient, but it also reduces the amount of time the aircraft can operate at its optimum level.

1.1.5.3 Traffic avoidance

In the most optimum situation, a departure route should be designed in such a way that there is no restriction that prevents an aircraft continuing its optimum flight profile. Both the arrival (STAR) and the departure (SID) should be deconflicted laterally or vertically. This optimum situation may not be reachable and therefore a balance must be found between the arrival and the departure routes. The spread of performance between aircraft in the climb is much greater than in the descent and a SID catering for all aircraft may present a height window prohibitively large for an unconstrained SID to be developed. One solution may be to develop different SIDs for different performance classes of aircraft. Compromises such as short intermediate level-offs for some aircraft, climb profiles at less than optimal rates, and route path changes, may also be needed. The overall efficiency achieved for all aircraft operating within the system must always be considered.

1.2 CCO DESIGN

1.2.1 General

1.2.1.1 Ideally, a CCO should be codified as part of a SID so that both flight crews and controllers have a fixed consistent procedure to refer to in advance. After departure, a path to the destination or airspace exit point that supports the most optimized vertical profile is desirable. Ideally, this will also provide for the shortest track distance to be flown. An unrestricted climb to cruise flight level with no speed restrictions is also desirable. Factors such as other traffic flows, terrain, restricted airspace, aircraft performance, and noise abatement requirements will all serve to modify the design of the (theoretical) most efficient path, often preventing the realization of the shortest path or the most efficient climb. The instrument procedure design must balance all of these factors to determine an optimal design.

1.2.1.2 Departure procedures should be designed according to the guidelines as set out in PANS-OPS (Doc 8168). However, PANS-OPS provide for obstacle clearance criteria only. For the application of a departure procedure, optimally designed for a CCO, additional altitude information may have to be provided. This CCO manual must therefore be seen as additional to the PANS-OPS design criteria.

1.3 BASIC DESIGN EXAMPLES

1.3.1 Initial steps

1.3.1.1 The aircraft fleet should be surveyed to obtain an expected maximum and minimum climb angle or rate. Ideally, the CCO-based procedure is designed so that no restrictions are placed on the procedure that would limit the aircrafts most efficient climb rate. The limits of the desired climb gradients serve as the basis for subsequent design decisions. There are a number of choices that must be made taking into account other traffic flows, terrain, restricted airspace, number and orientation of runways, surveillance capabilities, and fleet navigation capabilities. The CCO-based departure design may also require modifications to arrival paths. Therefore, an iterative design process commences with a goal to obtain the overall most optimized operational airspace model possible. It should be noted that, as all factors are taken into account, the shortest flight path may not always result in the best design.

1.3.2 CCO design example

1.3.2.1 The following depictions provide some basic CCO design examples. Each airspace situation must be evaluated on its own.

a) Basic CCO:

A basic CCO-based instrument procedure design allows for unrestricted climb rates for all aircraft. It requires that a significant amount of vertical airspace be set aside to protect the climb and may also extend the route in order to give lower performing aircraft the distance necessary to clear obstacles (see Figure 1-1).

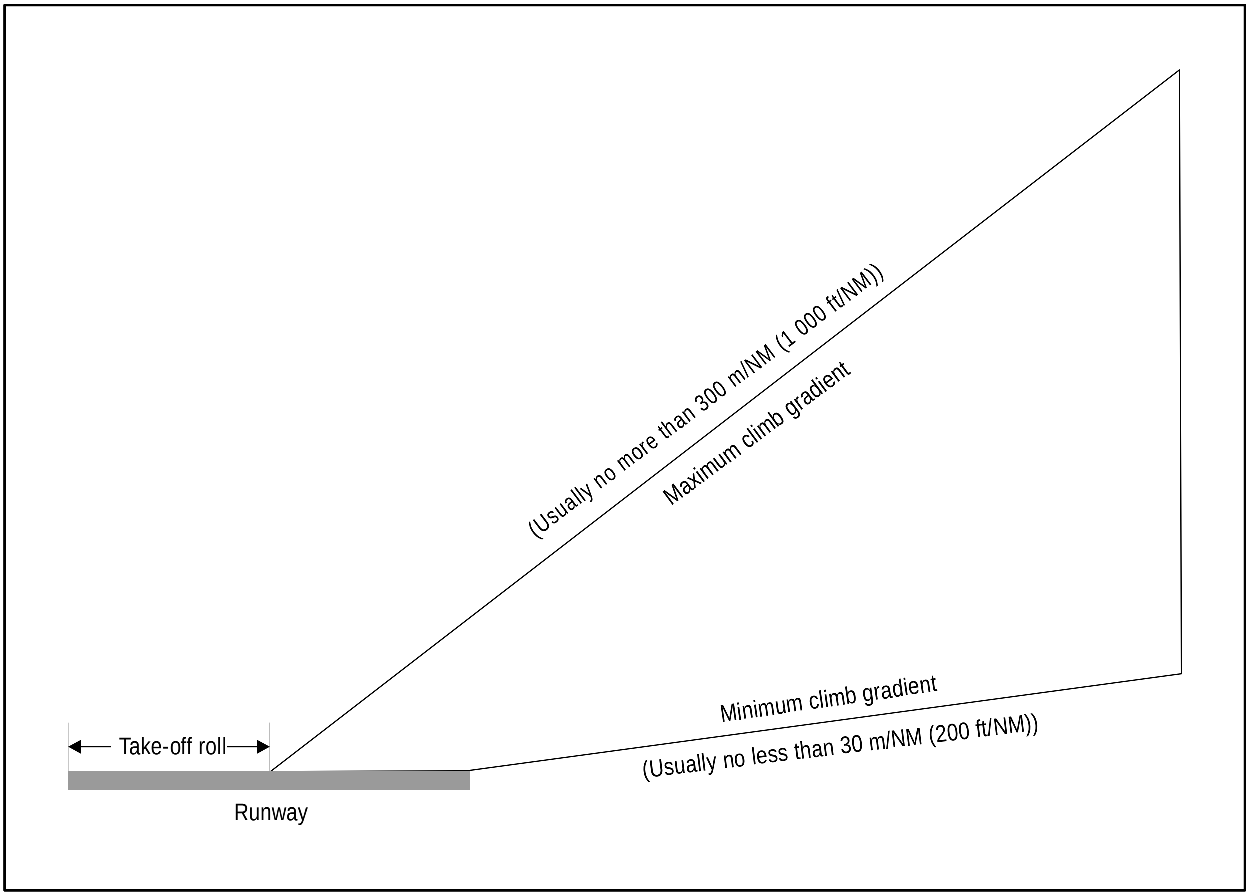

Figure 1-1. Basic CCO

b) Enhanced CCO design with multiple climb gradients:

Due to terrain or airspace limitations, it may be necessary to specify increased minimum climb rates for a portion or all of the SID. This can enable design of a shorter route length for those aircraft that are capable of higher climb rates. In such cases, one solution is to design two SIDs that both proceed to the same exit point; one for better performing aircraft and one for aircraft that require extra distance to gain altitude. Another alternative is to develop different SIDs to different exit points based on aircraft performance (see Figures 1-2 and 1-3).

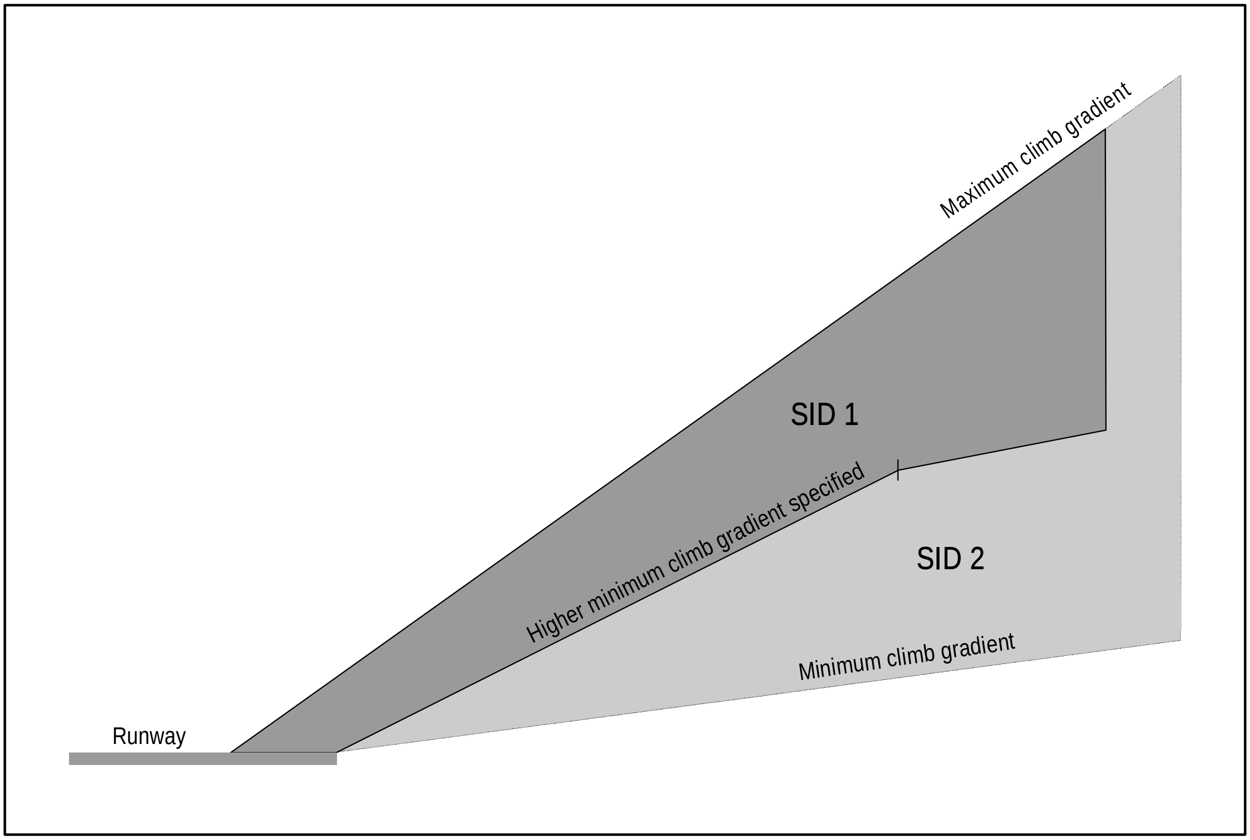

Figure 1-2. Multiple CCO SID design — profile view

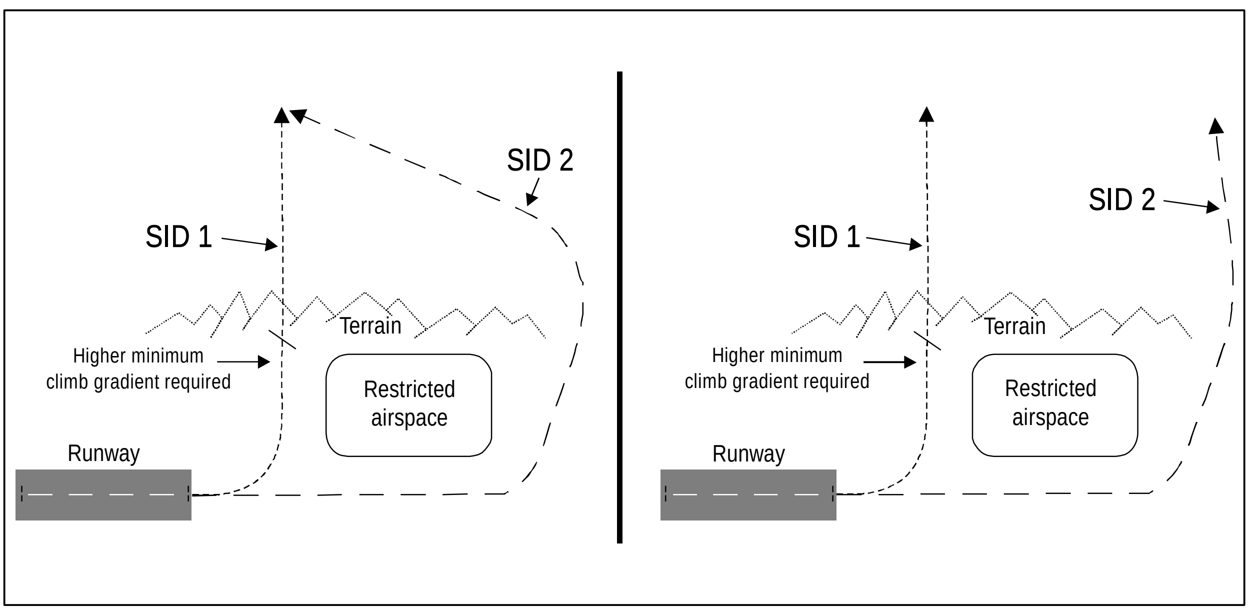

Figure 1-3. Multiple CCO SID design — top view

c) In facilities capable of surveillance at a level that permits vectoring aircraft, it may be advantageous to design departure routes that provide initial separation to take advantage of real time operational air traffic control instructions. This is a design difference between CDO and CCO. In general, CDO aircraft should be left on the designed route and not given a vector “shortcut” because a CDO is already descending at flight idle, thus descending at the steeper angle a shortcut requires may lead to an unstable approach. In contrast, tactical shortcutting of a CCO departure to take advantage of observed aircraft performance is desirable. Sending an aircraft direct to a subsequent fix on the procedure in order to reduce flight distance has the potential to produce a significant additional benefit with the least additional workload to both the controller and flight crew, but the ability of the aircraft to meet altitude constraints at subsequent waypoints must first be considered, such as:

1) single runway departure parallel to arriving aircraft allowing ATC to dynamically assign a shorter route in response to a real time traffic situation (see Figure 1-4);

2) multiple runways can allow for simultaneous departures and subsequent management of exact in-trail (see Figure 1-5).

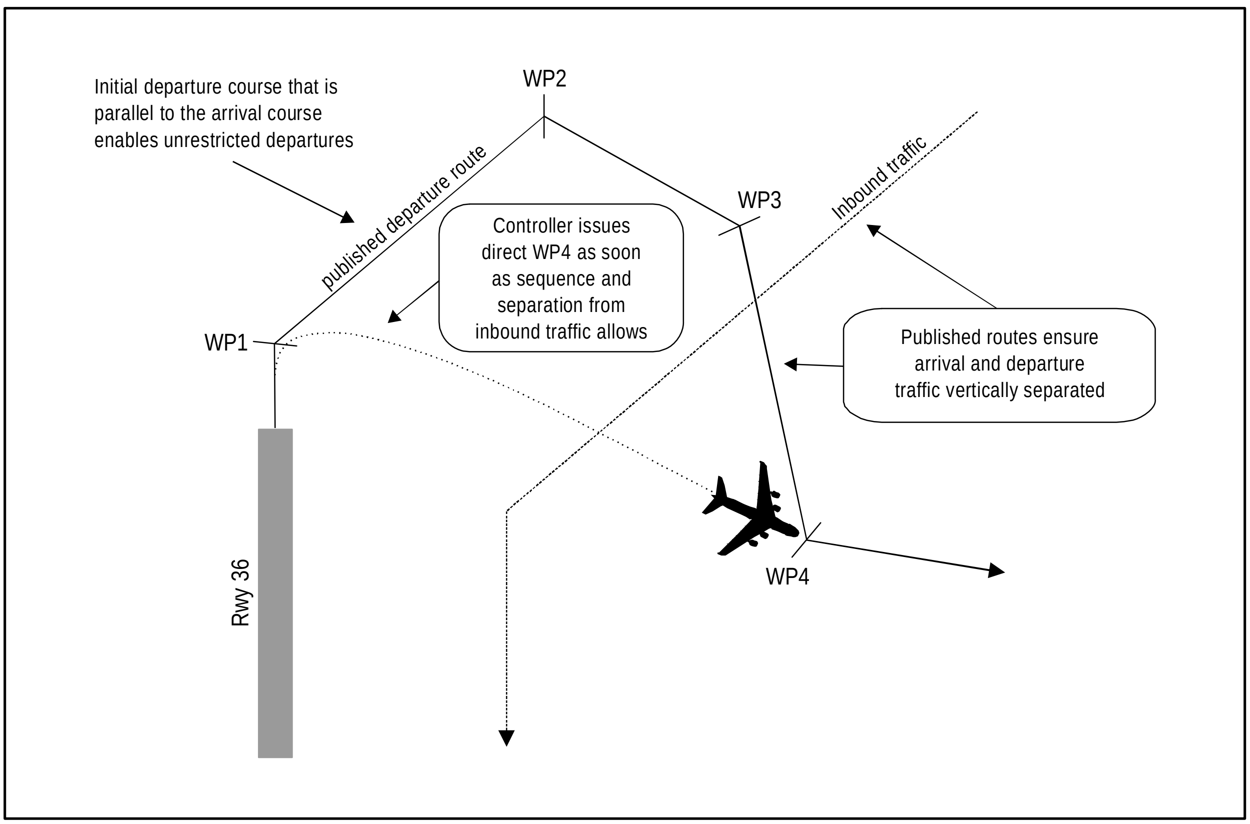

Figure 1-4. CCO SID parallel to arrival

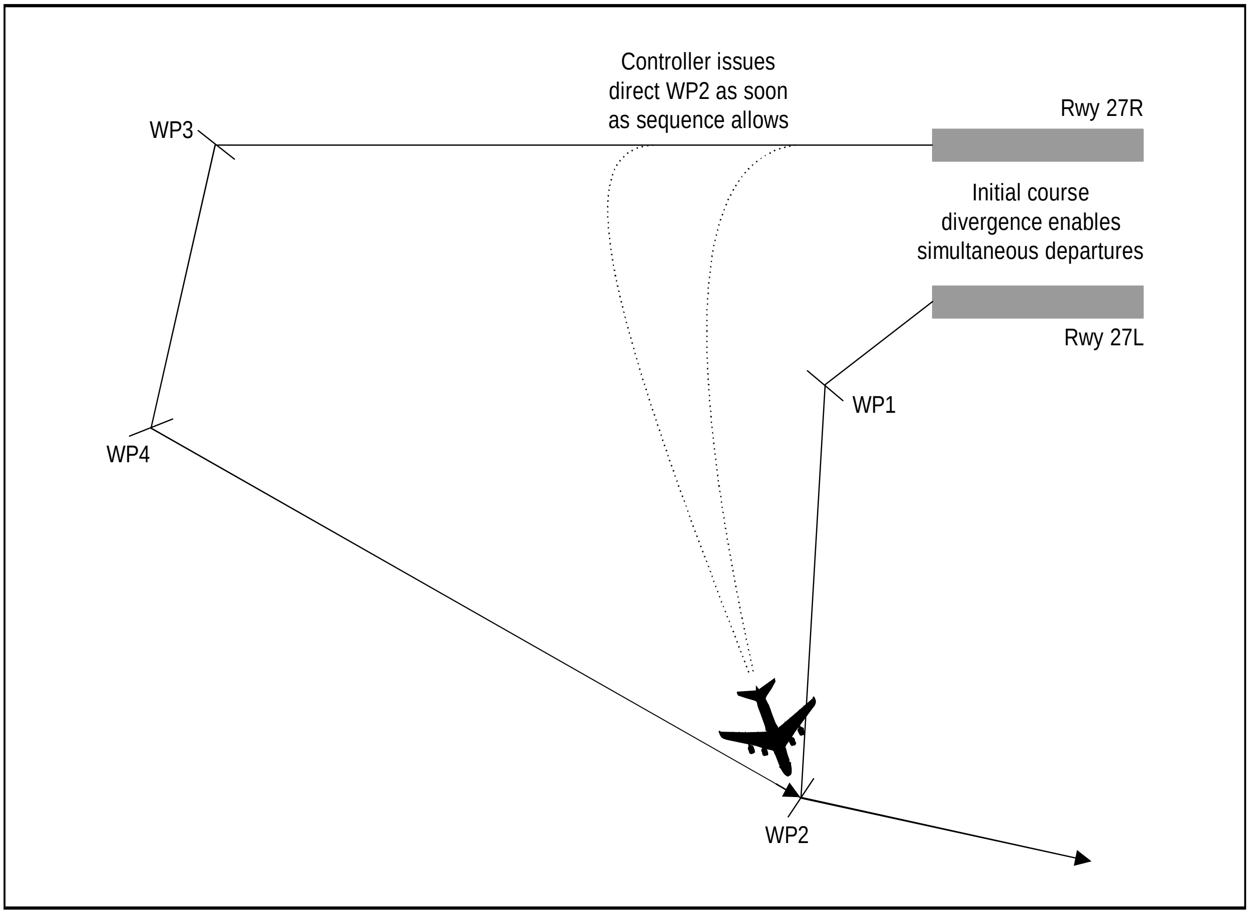

Figure 1-5. Multiple runway CCO SID design

1.3.3 Validation

1.3.3.1 Airspace concept validation

1.3.3.1.1 Validation of an airspace concept takes many forms. There is the validation initially by fast time and ultimately by real time ATC simulations that ensure the airspace concept works, the capacity of the airport is not compromised by the application of CCO and CDO, and the controllers can manage the workload. However, there is also the more fundamental issue of validity of the base assumptions pertaining to the climb and descent profiles of the target aircraft. If these assumptions are wrong then the basis upon which a fast or real time simulation would be based are flawed. Therefore, it is of vital importance that the airspace concept assumptions are initially validated by access to data for the airframe concerned over the range of expected take-off weights, temperatures, winds, etc. If this data is not available, then the use of aircraft simulators would be an alternative to collect data for a representative range of conditions.

1.3.3.1.2 Validation of an airspace concept is further elaborated in Doc 9992.

1.3.3.2 Instrument procedure design validation

The procedure will need to be designed in accordance with PANS-OPS (Doc 8168), Volume II, which identifies the validation requirements.

Chapter 2

SPECIFIC STAKEHOLDER ISSUES

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

2.1 AIRSPACE/INSTRUMENT PROCEDURE DESIGN

2.1.1 General

2.1.1.1 The departure route should be designed to allow the crossing of other inbound flows of traffic to one or more runways and one or multiple airports in the Terminal system, at ranges from the runway(s) that the crossing traffic flows will be naturally segregated by height when climbing or descending along their optimum profile. As the climb performance between aircraft is very diverse, it may prove to be impossible to accommodate all types of aircraft without intermediate level-off segments as part of the design. The aim must therefore be to design the most optimum vertical profile taking into consideration the following:

a) If necessary, the vertical profile could be bounded by minimum level requirements (for obstacle clearances, airspace restriction or traffic separation purposes), maximum level requirements (for traffic separation purposes) or level brackets (minimum and maximum).

b) In Figure 2-1, the interaction between descending arrivals and climbing departures is shown. It illustrates realistic climb and descent profiles. The shaded area shows where the climb and descent profiles are most likely to interact. For efficient design of flight paths that cross, it is better to cross early in the CCO or late in the CCO with the goal being to limit the potential interaction of SID/STAR flight trajectories.

2.1.2 Flight path considerations

2.1.2.1 The shortest lateral path to the destination or airspace exit point that facilitates an optimized climb profile is desirable. An unrestricted climb to cruise flight level with no speed restrictions is also desirable. Factors such as other traffic flows, terrain, restricted airspace, aircraft performance, and recommended noise abatement procedures will all serve to modify the design of the theoretical most efficient path. The instrument procedure design must balance all of these factors to determine an optimal design.

2.1.2.2 During the initial departure the thrust, speed and flap deployment may also be governed by any noise abatement procedures applied. Even after the noise abatement procedure, there may be a minimum noise routing requirement that will impact the flexibility available for the optimum management of the airspace.

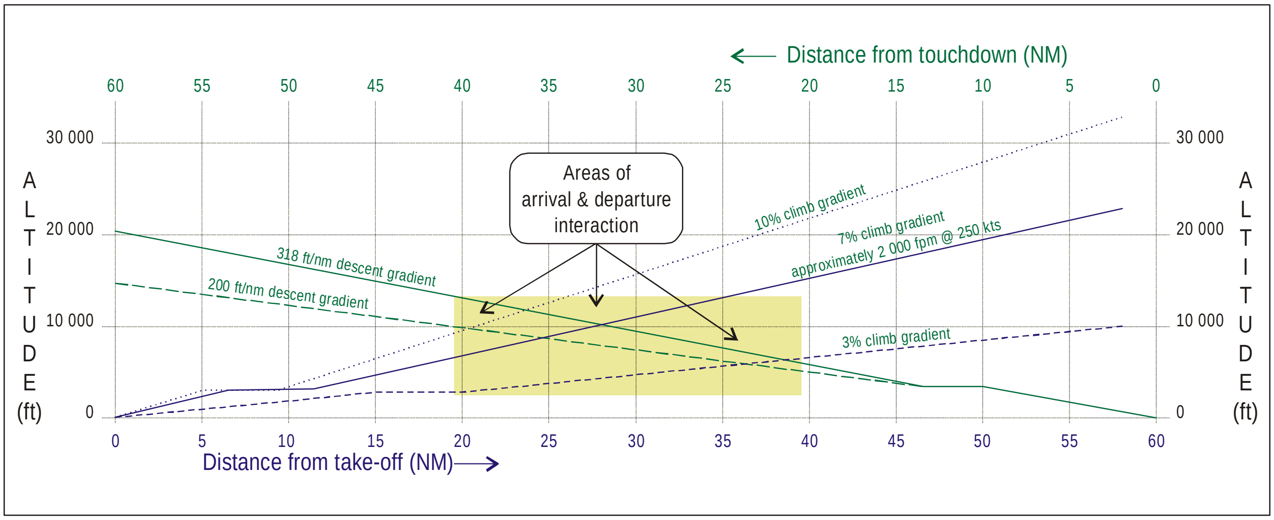

Figure 2-1. Possible vertical interaction between departing and arriving traffic

2.1.2.3 Level restrictions should not overly constrain the continuous climb profile. Rather, the profile 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 climb execution and allows for most efficient engine thrust settings.

2.1.2.4 If it is necessary for ATC to assign an initial climb level to the departure aircraft, efforts should be made to assign an altitude no lower than 1 500 m (5 000 ft) above ground level. The initial climb level should also take into account radio communication failure procedures.

2.1.3 Collaboration and standardization

2.1.3.1 A design of CCO-based procedures and any airspace changes that may be required needs to be a collaborative process involving the ANSP, aircraft operators, airport operators, the aviation regulator and, through appropriate channels, environmental entities, as necessary.

2.1.3.2 Expertise in FMS performance and flight procedure coding conventions (PANS-OPS (Doc 8168), Volume II, Part III, Section 2) should be included on the design team as the departure procedures will be stored in a navigation database. Specifically, when procedures involve demanding lateral manoeuvring, there may be a need for prior consultation with navigation database specialists.

2.1.3.3 As with 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.

2.1.4 Speed restrictions

2.1.4.1 In general, the application of speed controls is undesirable. However, where the turn radius has to be constrained, the radius can be minimized with the publication of speed limitations. Any published speed constraints need to be compatible with the minimum manoeuvring speed and optimum clean-up process of the aircraft.

2.1.4.2 Specific speed restrictions, to maintain separation between succeeding aircraft or to enable a smaller turning radius, may be required to allow CCO in high traffic density areas or in areas with airspace and terrain constraints. Speed constraints reduce the flexibility of the CCO but can aid in enabling a CCO-based procedure where it might not otherwise be possible. Aircraft and FMS-specific limitations should also be taken into account.

2.1.4.3 An additional consideration is that requiring speed constraints soon after the departure end of the runway may delay flap retraction and thus increase noise production in a noise sensitive part of the flight, as well as increasing both fuel burn and emissions.

2.1.4.4 Applying a noise abatement departure procedure type to the design may result in a speed profile that has an effect on the turn radius. This can be illustrated by referring to one of the example noise abatement procedures as shown in PANS-OPS (Doc 8168), Volume I, Part I, Section 7, Chapter 3, Appendix:

a) In case of the NADP 1, where the initial take-off will be based on a constant speed (V2 + 10 or 20 kts IAS) until the acceleration altitude (maximum 900 m (3 000 ft) AGL), the initial speed remains relatively low and therefore the turn radius is smaller.

b) In case of an NADP 2, with a lower acceleration altitude, the initial speed will increase rapidly and therefore may have an effect on the nominal flight path during the initial turns where often noise or obstacle clearance criteria play a role. This may result in a larger turn radius.

2.1.4.5 Proposed permanent speed restrictions need to be coordinated between all stakeholders. Speed limitations requiring jet aircraft to fly at speeds lower than 430 km/h (230 knots indicated airspeed (KIAS)) should normally not be implemented due to the possible significant increase in drag and fuel burn.

2.2.4.6 When deciding on the design of the route and the position of the waypoints, the previous factors must be carefully analysed.

2.1.5 Publications and charting issues

2.1.5.1 It is recommended that specific information relating to the CCO be published through established channels to ensure stakeholder awareness.

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

2.1.5.3 Any speed and level restrictions should be clearly depicted on the chart.

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

2.1.6 Database coding

2.1.6.1 Unless operational requirements dictate otherwise, procedures should use track to fix (TF) legs. Direct to fix (DF) and course to fix (CF) legs are also used to a more limited extent and may provide operational flexibility in situations where a TF leg does not meet operational requirements.

2.1.6.2 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 improved vertical navigation (VNAV) accuracy. However, the need for an RF leg capability will necessitate that an RNP navigation specification be applied to the procedure.

2.2 FLIGHT OPERATIONS

2.2.1 General

2.2.1.1 The optimum CCO is flown as a continuously climbing flight path with a minimum of level flight segments and engine thrust changes and, as far as the maximum procedure speeds allow, in a low drag configuration. After departure, aircraft speed and configuration changes have to take place, including the retraction of flaps and landing gear. This configuration process should be managed with care in order to minimize the risk of unnecessary thrust variations and should conform to the standard procedures for configuring the aircraft for departure as detailed in the aircraft operating manual. If available, and whenever possible, an unrestricted vertical path should be used.

2.2.1.2 The flight crew should have the flexibility to manage the aircraft's speed and rate of climb within the constraints of the procedure. For aircraft equipped with FMS and VNAV capabilities, an optimum climb can be planned and executed with a fixed lateral flight path stored in the navigation database.

2.2.1.3 The instrument flight procedure may have been designed to facilitate CCO all the way to the airspace exit point. The actual procedure to be flown should be clearly indicated on the appropriate chart. The availability of the full CCO may depend upon prevailing traffic density levels and on controller workload.

2.2.2 Take-off procedure

2.2.2.1 For each airport or runway, or ideally even for each SID, a different departure procedure could be the optimum. Standardization in cockpit procedures is extremely important. The take-off phase of flight is one of the phases with the highest workload.

2.2.2.2 Immediately after take-off, navigation from visual to instrument phase takes place. Accurate lateral navigation is required while at the same time the acceleration process takes place. The possibility of an engine failure must continuously be kept in mind. Engine thrust setting, navigation instrument setting and autopilot coupling (if available) must take place while at the same time the flap retraction schedule, in balance with speed and acceleration, must be managed.

2.2.3 Unrestricted climb

2.2.3.1 An unrestricted climb is the most optimum climb operation. Assigning intermediate level-offs after the aircraft is airborne requires the flight crew to take additional actions, and may also require additional communication to take place. Each communication via radiotelephony introduces the possibility of error with the potential for misunderstanding instructions, which may result in level busts.

2.2.3.2 An operation without the need for additional instructions in the lateral or vertical plane is preferred. In many cases, issuing additional instructions is necessary, especially in busy and complex airspace. For this reason, the design of a departure route that allows for minimum intervention has many safety advantages.

2.2.4 Transition altitude (TA)

Where a continuous climb continues above the TA, and there is a significant difference between the aerodrome QNH (altimeter sub-scale setting to obtain elevation when on the ground) and the standard pressure, the vertical flight path will be affected and a temporary change of the vertical climb rate may be observed.

2.2.5 Cockpit workload

2.2.5.1 Cockpit workload should be considered in the design of any continuous climb procedure. A procedure designed for CCO should keep the workload required during a continuous climb within the limits expected for normal flight operations. The lateral and vertical flight paths 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 modifications may not be possible, causing a significant decrease in the ability of the aircraft to accurately fly a fully optimized profile.

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

2.2.6 Flight crew training

2.2.6.1 Optimal execution of a CCO procedure may require additional action to be taken by the pilot. Effective and precise execution of a CCO procedure requires that procedure-specific issues be briefed prior to take-off. These may include the following:

a) speed restrictions;

b) level constraints or crossing restrictions;

c) take-off and noise abatement techniques;

d) the level of automation to be used;

e) the possible effect of wind, atmospheric pressure, altimeter setting and expected icing conditions;

f) the effect of the transition altitude; and

g) ATC phraseology.

2.3 ATC TECHNIQUES

2.3.1 General

2.3.1.1 Maximum effective execution of SIDs which supports CCO procedures using laterally and/or vertically defined routes requires flexible airspace design and sectorization, with sufficient space to allow the aircraft to climb in accordance with the parameters computed by the FMS. A flight path extension will place the aircraft above the optimum vertical path and the aircraft may be required to level off in response to airspace limits or other air traffic, thus reducing efficiency. A tactical shortening of the route through instructions to proceed direct to a following waypoint will place the aircraft below the initially anticipated vertical path but, by saving distance and thus flight time, can significantly improve overall efficiency. In this case, consideration should be given to aircraft performance to ensure that all level restrictions can be satisfied.

Note.— The pilot-in-command can reasonably be expected to attempt, when feasible, a continuous climb 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.

2.3.1.2 Ground tracks of CCO based on vectoring will be more dispersed than those based on FMS-generated profiles, which are calculated on a fixed, predefined lateral route. Thus where noise is an issue, vectoring may allow for a dispersion of the noise footprint.

2.3.2 CCO and airport arrival rate (AAR) considerations

2.3.2.1 CCO should not compromise the AAR and should be considered as “the art of the possible” within the AAR constraint. Variations in aircraft performance, including climb rates and speeds, may affect other published procedures during both arrival and departure. Traffic demand may dictate tactical interventions by the controller.

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 CCO procedures and the profiles associated with CCO. Effective CCO implementation requires 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, the trade-offs inherent in the specific CCO-based instrument procedure design, and be aware of the need for unambiguous controller-pilot communications.

2.3.3.2 If resources are available, joint ATC/flight simulations should be conducted to allow both pilots and controllers to gain a better understanding of how the CCO design may be successfully implemented.

2.3.4 Controller radio transmission workload

In general, a published CCO-based procedure should require fewer controller radio transmissions than vector based departure procedures due to the fact that the complete aircraft trajectory is issued via the SID prior to departure. The controller can ideally monitor a consistent flight path with little need for intervention. Radio transmissions will increase when necessary to vector aircraft away from the procedure to maintain in-trail separation or to avoid conflicts with other aircraft. Sending an aircraft direct to a subsequent fix on the procedure in order to reduce flight distance has the potential to produce a significant additional benefit with the least additional workload to both the controller and the flight crew, but the ability of the aircraft to meet altitude constraints at subsequent waypoints must first be considered.

2.3.5 ATC facilitation

2.3.5.1 Dependent upon the instrument procedure design, the CCO may start anywhere from the departure end of the runway onward. For optimized fuel efficiency and reduced emissions, a CCO should start at the departure end of the runway with the clearance being issued by ATC prior to take-off roll.

2.3.5.2 The application of CCO procedures in the air traffic system, including the impact on aircraft sequencing and departure rates, depends on the level of traffic density and types of flights involved. Application of the procedures could vary during hours of operation. Except for very complex airspaces, it should be possible to enable some degree of CCO at most airports.

2.3.5.3 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, CCO using pre-planned profiles should be available from the departure end of the runway, using the full capability of airborne and ground-based systems.

2.3.5.4 ATC units should seek to optimize both the number of and extent of CCO issued over time.

2.3.6 Letters of Agreement

2.3.6.1 In preparation for the implementation of CCO-based procedures, Letters of Agreement between affected ATC units and sectors should be reviewed and updated as necessary, taking into account that CCO may entail changes to both vertical and horizontal flight paths.

2.3.6.2 Letters of Agreement should allow level windows for the aircraft handover, thereby avoiding, to the greatest extent possible, the need for aircraft to level off at the handover.

Chapter 3

CCO IMPLEMENTATION OVERVIEW AND PREREQUISITES

3.1 INTRODUCTION

This section offers a model process for implementing CCO-based procedures. This implementation guidance is not meant to be an exact blueprint and may need to be modified to account for local requirements, issues and considerations. The collaborative process should be used by the design team that is implementing CCO-based procedures. It is important that the ANSP, aircraft operators, the airport operator, procedure designers, and other stakeholders work together to develop the procedures. Collaboration is important because it allows individuals representing all required areas of expertise to contribute positively to the outcome, thus producing better procedures than any one individual with only a limited perspective can produce. When implementing CCO, it is important to balance the benefits of CCO with the effects of CCO on other operations within the airspace as a whole.

3.1.1 CCO 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;

b) collaboration between ANSP, aircraft operators and the airport operator is essential;

c) CCO-based procedures may require significant airspace changes;

d) CCO-based procedures should not be considered in isolation but rather in the light of the total current operations, e.g. the implications for arrivals and any planned changes, such as implementation of airspace changes, CDO, new procedures or advanced automation systems should be taken into account;

e) the effectiveness of CCO facilitation relies on accommodating the optimum climb profile possible, avoiding unnecessary and non-optimal climb restrictions, and allowing the aircraft to fly at speeds, climb rates and on paths that permit them to operate as efficiently as possible;

f) an optimum CCO-based procedure provides the capability for an aircraft to fly a pre-planned vertical profile that allows the aircraft to climb without restriction. Published level restrictions should be defined so as to allow, to the maximum extent possible, the aircraft to climb unimpeded;

g) where applicable, noise abatement departure procedures (e.g. PANS-OPS (Doc 8168) NADP 1 and NADP 2) are included within the CCO-based instrument procedure design and considerations, such as climb rate limitations, SID allocation, or lateral path modifications to meet noise requirements, are accomplished without compromising the ability to optimize the climb;

h) aircraft climb profiles should be optimized for operational and/or fuel reduction purposes;

i) appropriate use of speed management can help to optimize the climb profile;

j) a complete continuous climb from take-off to cruise is ideal and should be initiated whenever tactically possible;

k) a partial continuous climb for part of the procedure or even limited to within individual sectors will still be worthwhile.

l) where CCO is to be facilitated tactically, ATC coordination agreements need to be established so as to avoid potential confusion;

m) CCO is the "art of the possible" and should not adversely affect capacity, safety or other operations. Start simple and build on experience; such an approach will prepare for new technologies;

n) a CCO-based procedure should not cause a greater net operational disadvantage when the entire area of operation, including any CDO, is considered;

o) assessing the performance baseline is an essential first step since an optimum level of CCO may already exist; and

p) 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

3.2.1 Figure 3-1 provides an overview of a potential programme plan to successfully implement a CCO-based procedure at a specific airport. It addresses the totality of the programme from initial concept through planning, implementation and review. The early steps are primarily associated with concept, education, and winning support from top management.

3.2.2 After a go-ahead has been given, Table 3-1 below provides a basis upon which a project management plan could be developed. Such a table could be part of a State PBN action plan.

3.3 IMPORTANCE OF EFFECTIVE COLLABORATION

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

3.3.2 Appendix 1 to this manual contains example CCO collaborative implementation group responsibilities.

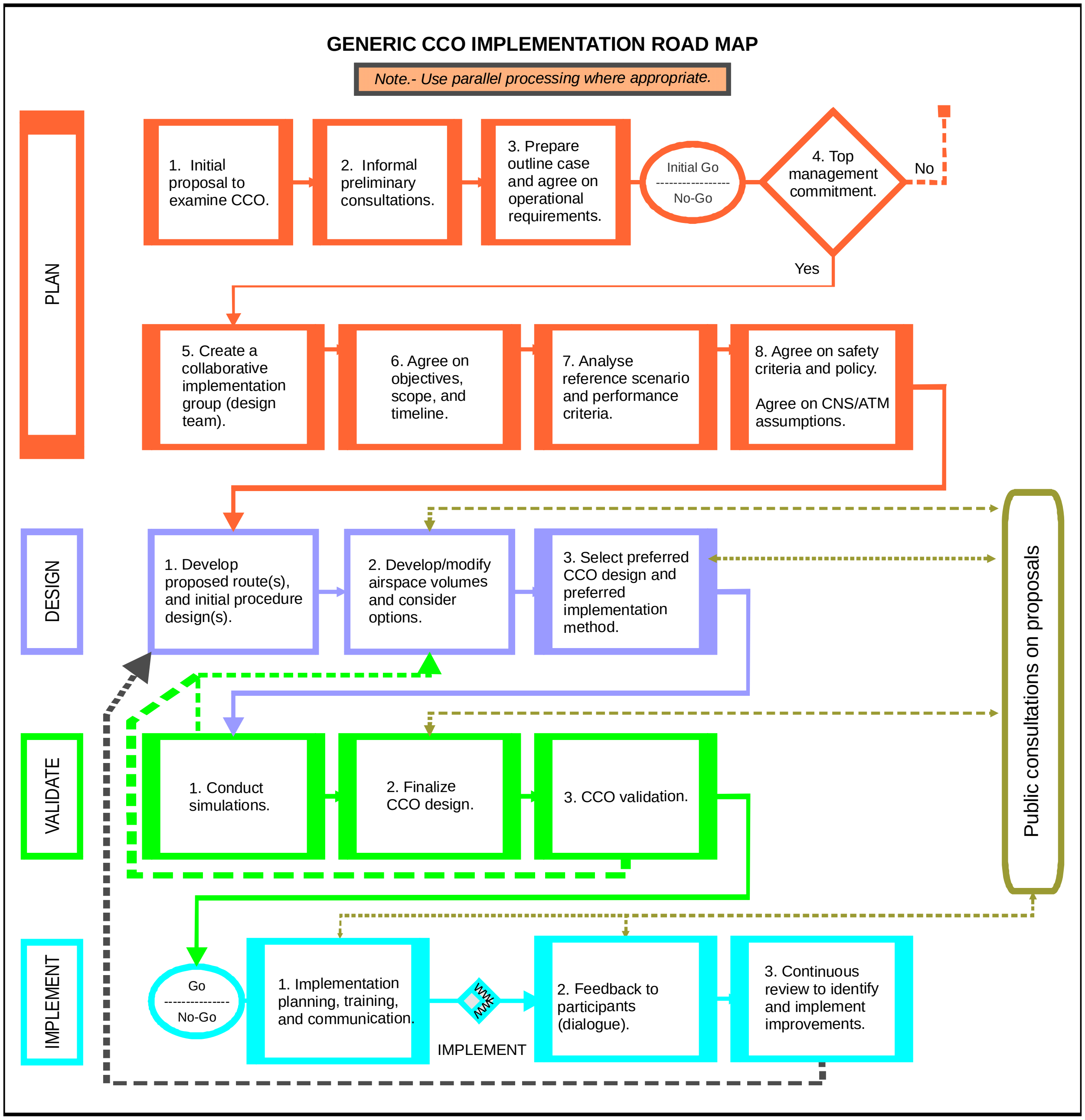

Figure 3-1. CCO implementation process diagram

3.4 COMMUNITY RELATIONS AND CONSULTATION

Introducing CCO may offer benefits in terms of reduced fuel use and emissions, but may also change the nature or locations of noise impacts. While the majority of the populated area may benefit from reduced noise from CCO or while associated flight changes may not occur in the most noise-affected areas, there may be a minority for whom the noise increases. External consultation with interested parties may therefore be required 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 CCO-compliant procedures could conceivably concentrate flights over newly affected areas.

3.5 POLICY CONTEXT

3.5.1 Understanding the policy context is important for making the case for local CCO implementation and ensuring high levels of participation. CCO may be a strategic objective at the international, State, or local level, and therefore may trigger a review of airspace structure. For example, CCO may not affect flight performance within the area of the most significant noise contours, i.e. those noise levels upon which decision-making is based. It is important, therefore, not to raise unrealistic public expectations, but to communicate successful implementation and positive performance, particularly relating to emissions reduction.

3.5.2 As a part of the safety assessment, a transparent assessment of the impact of CCO 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 CCO should be seen as the first step towards continuing CCO improvements. A "no-blame" culture will be essential to allow open and candid discussions 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, CCO may not be possible. In such cases, it is important to compile a report detailing the process used to reach the final conclusions and the reasoning for rejecting the introduction of CCO. Such a report will facilitate dialogue with the community and the regulating authorities. It will also produce useful information for any future considerations of CCO implementation.

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				

Part B

IMPLEMENTATION GUIDANCE

Chapter 1

INTRODUCTION TO IMPLEMENTATION PROCESSES

The following steps provide a map to CCO 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 four main CCO implementation phases:

a) planning;

b) design;

c) validation; and

d) implementation.

———————

Chapter 2

PLANNING PHASE

2.1 INITIAL PROPOSAL TO CONSIDER CCO

2.1.1 The initiation of CCO implementation may be proposed by any operational stakeholder. The individual proposing CCO is hereinafter referred to as the "initiator".

2.1.2 It may not be possible for the initiator to undertake a full preliminary CCO viability assessment at the introductory 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 CCO, 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.

2.1.3 In light of this informal review against the above points, the initiator should prepare a short preliminary report to secure interest from operational stakeholders. It is important to engage all key operational stakeholders at an early stage. Collaboration with all stakeholders as early as possible allows for rapid development of a successful design. This can be achieved very effectively through a dedicated CCO workshop, at local, regional and/or national levels, 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 CCO-related opportunities, benefits, gaps, issues and risks from different operational perspectives;

c) decide, jointly, whether CCO is considered sufficiently viable 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.

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

a) representatives of the aircraft operators, including:

1) policy/decision makers;

2) pilot(s); and

3) technical support (including FMS expertise);

b) representatives of the ANSP, including:

1) policy/decision makers;

2) management and controllers of affected ATC units;

3) airspace designers; and

4) procedure designers;

c) representatives of the aerodrome operator, including the:

1) environment department; and

2) operations department;

d) optionally, the following participants:

1) aviation regulators;

2) Ministry of Transport;

3) industry representatives;

4) international organizations or agencies (where appropriate);

5) ministry responsible for the environment;

6) military; and

7) representatives from the local community.

2.2 PREPARE AN OUTLINE CCO CASE

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

a) description of the proposed CCO, its stimulus and the policy context;

b) description of practical support available;

c) estimation of potential benefits and costs (outline benefits are covered later in this manual);

d) implementation road map, including approvals required, "go-no-go" decision points, proposed working arrangements, points of contact and proposed lead stakeholder (including project leader if known);

e) top commitment requirements (what is expected from CCO policy/decision makers);

f) recommendations; and

g) annexes:

1) description and outcomes from the workshop;

2) potential CCO facilitation candidates;

3) gaps and risks.

2.2.2 For CCO implementation to be successful, senior management commitment is essential from each stakeholder in order to give the work priority, drive progress and provide 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 CCO implementation to progress past a certain point[1].

2.3 ESTABLISH A CCO COLLABORATIVE IMPLEMENTATION GROUP DESIGN TEAM

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

2.3.2 Early tasks will include the following:

a) ensuring a common understanding of the work undertaken so far;

b) identification of skill requirements, co-opting members and/or informing supporters of potential support requirements accordingly;

c) agreement on the initial road map — the road map in this guidance may be used, but with more detail on the planning phase;

d) agreement on roles and responsibilities (example responsibilities are shown in Appendix 1); and

e) establishment of consultation and reporting processes.

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

2.4 JOINT PRELIMINARY ASSESSMENT

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

2.4.2 This will require joint consideration of:

a) what is the baseline case;[2]

b) what performance changes, i.e. positive or negative, could arise from CCO;

c) what direct and indirect barriers, risks and enablers exist (at a high level); and

d) what CCO facilitation alternatives and combinations should be considered.

2.4.3 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 noise sensitive areas;

b) how do arrivals and departures interact;

c) by using data from, for example, track monitoring systems and 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) the degree to which climbs are interrupted at present as a result of traffic flow conflicts or due to the instrument procedure design;

e) what relevant plans or developments are under way within the airspace and at the airport;

f) what are the relevant regulations and policies, e.g. consultation requirements;

g) what capabilities will be needed, in terms of, e.g. ATC and flight simulation, monitoring and feedback loops;

h) what related effects may exist, e.g. effects on capacity or departure profiles;

i) what risks exist and what mitigation is required, e.g. how may traffic growth affect the ability to perform CCO;

j) how might consultation obligations delay CCO implementation;

k) what change to noise impact may occur, e.g. a change to geographical locations of noise impact and concentration, or dispersion of noise impact; and

l) what "quick-win" opportunities exist, e.g. rapid implementation of tactical CCO in very low traffic scenarios.

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

2.5 STRATEGIC PLANNING

2.5.1 It is important that all stakeholders agree to and support the strategic plan for implementation of the selected CCO solution.

2.5.2 A joint agreement documenting the following issues will be required:

a) basic project management;

b) phases of continuing CCO development (list the 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 CCO implementation assessment purposes;

f) CCO implementation success rate, e.g. percentage of CCO 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.

Chapter 3

DESIGN PHASE

3.1 DEVELOP CCO OPTION(S)

3.1.1 At the design phase, CCO implementation options are described with adequate explanations:

3.1.2 The options now need 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 instrument 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; and

f) update the initial safety assessment.

3.2 CONSIDER OPTIONS AND JOINTLY AGREE ON PREFERRED IMPLEMENTATION

3.2.1 It is essential to consider all of the options for facilitating CCO implementation as well as the scope of any CCO 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.

3.2.2 These alternatives could include:

a) CCO 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 CCO from different levels during different traffic density levels; and

h) initiating CCO from the departure end of the runway to top of climb in less busy periods.

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Chapter 4

VALIDATION PHASE

4.1 SIMULATE AND VALIDATE

4.1.1 At the validation phase, 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. Issues encountered in simulation may require a reversion to the design phase of the project to correct any observed discrepancies.

4.1.2 It is necessary to simulate a range of traffic profiles encompassing the climb and descent profiles likely to be encountered at the airport to ensure that the design does not lead to unsafe or inefficient operations. Depending on the project complexity, simulation may consist of flight simulation, fast-time simulation (FTS), real-time simulation (RTS), or a combination of some or all of these simulation methods.

4.1.3 Flight simulation may be accomplished in cooperation with one or more aircraft operators to confirm predicted aircraft performance and to highlight areas that may need to be modified in the CCO design.

4.1.4 FTS is useful for gathering and refining the data that are necessary to define a trial. FTS uses predefined procedural rules that are input into a computer model which return a result set. FTS does not require the resources necessary to enable real time participation of controllers or pilots and so can usually be accomplished for less cost than RTS. When performing an FTS study, it is important that the people involved have confidence that the model used gives a realistic representation of the real-life system being simulated. All stages of the model development should ensure that the behaviour of the model and the definition of the traffic and procedures are as representative of a real-time system as possible.

4.1.5 During an FTS, the radar image of what is happening during the simulation may be checked and some preliminary analysis may be performed to ensure that the procedures simulated are manageable in a real-time system. The result is that the number of problems encountered during the operational trial is minimized as much as possible. Using the FTS model to observe the airspace and the levels of traffic, new ideas and procedures may be developed that would otherwise not be thought of until much later in the process, thus enabling changes using a minimum expenditure of resources.

4.1.6 An RTS attempts to realistically replicate ATM and aircraft operations, and requires the active participation of proficient controllers and simulated or “pseudo” pilots. In some cases, sophisticated RTS can be linked to multi-cockpit simulators so that realistic flight performance is used during the simulation. RTS may require a significant amount of resources.

4.1.7 One of the difficulties that can be encountered with RTS is that the navigation performance of the aircraft is too perfect. “Aircraft” in an RTS may operate with a navigation precision that is unrealistically good, given realities of weather, individual aircraft performance, etc. In such cases, variables from live operations may be analysed and these can be scripted into the RTS.

4.1.8 Scripting an event into an RTS is done to deliberately introduce a disturbance into the RTS system, with the goal of exercising the planned system in a more rigorous manner than would be acceptable during operational trials. Thus, responses to events that would not normally be encountered in live trials may be observed and analysed, and allow improvements to be developed where necessary.

4.1.9 Successful flight and ATC simulation should complete the CCO design.

4.1.10 Based on the results of simulations, 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.

Chapter 5

IMPLEMENTATION PHASE

5.1 DECISION POINT (GO-NO-GO)

5.1.1 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.

5.2 IMPLEMENTATION PLANNING

5.2.1 A 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 CCO trial need to be established.

5.2.2 All parties involved in the CCO 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.

5.2.3 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.

5.3 IMPLEMENTATION TRAINING

5.3.1 To support CCO implementation, local guidance and awareness material should be produced and promulgated.

5.3.2 The collaborative group should meet to ensure that everyone involved understands the overall intentions and operation of the procedure and their respective roles.

5.3.3 Training should be coordinated among stakeholders so they are all trained using similar material.

5.3.4 The training and awareness material could include:

a) CCO benefits and their local importance;

b) training requirements for the selected (open or closed) CCO facilitation method;

c) a simple pamphlet describing the aims of and requirements for CCO;

d) the individual roles and responsibilities relevant to the conduct of individual CCO flights; and

e) a method for providing ongoing feedback on progress to all participants.

5.3.5 Training should be conducted as close to the implementation date as practical to ensure that training is current on the day of implementation.

5.4 COMMUNICATION

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

5.5 PERFORMANCE MONITORING AND ASSESSMENT

5.5.1 During the trial period, performance monitoring is important and there is a need to correlate:

a) the extent to which a CCO was offered and how it was followed;

b) aircraft identification;

c) flight performance information; and

d) reasons for non-compliance, if any.

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

5.5.3 Performance assessment should be based on the progress and results of the trial. It should cover the key performance areas of most relevance for local circumstances. 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) environmental impacts, including noise and emissions;

e) effect on capacity;

f) effect on training requirements; and

g) feedback to participants.

5.6 FULL IMPLEMENTATION

5.6.1 Following a successful trial outcome, full implementation of the CCO should be progressed and coordinated through established channels.

5.7 CONTINUOUS REVIEW AND IMPROVEMENT

5.7.1 Regular feedback on CCO performance to all involved operational stakeholders is critical to the successful implementation and continued application of CCO. Equally critical is offering those involved with CCO 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.

5.7.2 It is important to inform the community of ongoing progress and to seek their opinions and perceptions on the effects of CCO through established channels.

5.7.3 The CCO collaborative working arrangement, e.g. the CCO implementation group, should also assume an ongoing responsibility for the following:

a) review of CCO 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 CCO performance; and

d) implementation of improvements.

Appendix 1

EXAMPLE OF CCO COLLABORATIVE IMPLEMENTATION GROUP DESIGN TEAM RESPONSIBILITIES

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 CCO procedure (e.g. its definition and scope and when and how it is to be applied).

2. CCO facilitation is designed in accordance with the criteria detailed in PANS-OPS (Doc 8168), Volume II.

3. Once draft procedures have been produced, an "interim CCO assessment" is undertaken covering safety, capacity and workload issues.

4. Following a successful "interim CCO assessment" and adequate training of controllers and participating pilots, the provisional procedures are implemented as a limited trial.

5. Following a successful trial, CCO use is introduced or expanded according to a plan developed by the members and approved by the appropriate authority.

6. Adequate local guidance, training and promotional activities and materials are developed and applied to maximize the achievement of CCO. This is combined with regular feedback and reporting on CCO compliance.

7. Once the CCO 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 among all members.

— END —

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