CANSO

LONG-RANGE AIR TRAFFIC FLOW MANAGEMENT CONCEPT WHITE PAPER

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Acknowledgements

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Executive Summary

The concept of Long-Range Air Traffic Flow Management (LRATFM) has been in discussion for many years. Despite this, the actual nature of the concept has long eluded an agreed definition. Developed by Air Traffic Flow Management (ATFM) experts through the CANSO ATFM/A-CDM Workgroup, this White Paper proposes such a definition, while at the same time tracing its history, origins, and evolutions through early initiatives such as AEROTHAI's Bay of Bengal Cooperative ATFM System (BOBCAT) and NATS' Extended Arrival Management. LRATFM, then, is a sub-element of the ATFM concept. It can be defined as:

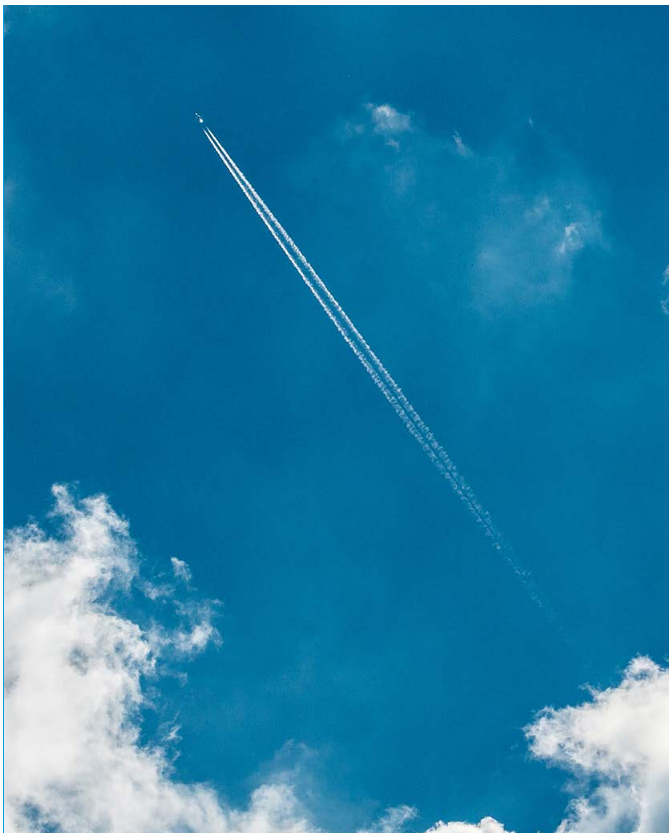
"The integration of ATFM solutions to deliver a collaboratively balanced flow of long-haul and short haul aircraft to an ATM resource (airport, waypoint, or a sector of an airspace)."

In preparing this document, the CANSO ATFM/A-CDM Workgroup has explored this sub-element in detail, drawing on the experiences of its members, many of whom have designed and implemented instances of LRATFM. The document begins with an introduction of the broad environment in which ATFM is delivered, followed by an introduction of the LRATFM sub-element. The introduction of LRATFM is complemented by a description of what the LRATFM concept could be if implemented in a *"perfect world"* scenario. The perfect world scenario is provided as a starting point for LRATFM implementation initiatives, and as a way to identify the challenges to address based on a real operational environment. The document also explores the way in which the horizon of current ATFM operations can be expanded to include long-haul flights through LRATFM concept. This is expected to become increasingly possible as cross-border operations and collaborative decision-making mature. The integration of LRATFM sub-element into the current ATFM operations can be expected to contribute commensurably to the benefits already delivered by the existing ATFM.

Following the introduction of the LRATFM concept and scenario, conceptual considerations and implementation recommendations drawn from completed trials and operational implementations are provided to support ANSPs in developing their own LRATFM implementation plan.

These considerations note that LRATFM should be applied as part of a holistic ATFM solution, a solution that should be time based rather than speed based, and that integration of the LRATFM system and the arrival management (AMAN) system is desirable but not mandatory.

Finally, building on the perfect world scenario, possible applications of LRATFM in various regions are provided to guide and align the implementation efforts around the globe. The list of possible applications shows the LRATFM concept can be made operational in all regions with the tailoring of procedures and a planned collaborative approach by all stakeholders.



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ATFM Basics

This chapter provides an overview of Air Traffic Flow Management (ATFM) and how it is currently implemented around the globe. Understanding the basics of ATFM can help readers better understand its evolution toward Long-Range ATFM (LRATFM), and how “conventional” ATFM and LRATFM can be integrated.

1.1 Overview of ATFM

Air Traffic Management (ATM) is defined as the dynamic, integrated management of air traffic and airspace including air traffic services (ATS), airspace management (ASM), and air traffic flow management (ATFM). This comprehensive concept, having evolved in response to ever-increasing traffic demand and rising complexity in airspace usage, enhances the conventional ATS processes with improved planning through ASM and ATFM. The comprehensive concept allows for more well-planned management of complex networks of airport and airspace resources to facilitate air traffic safely and efficiently.

Given that ATFM is an important element of an ATM system, *Annex 11 to the Convention on International Civil Aviation* specifies in Section 3.7.5 that,

“Air traffic flow management (ATFM) shall be implemented for airspace where air traffic demand at times exceeds, or is expected to exceed, the declared capacity of the air traffic control services concerned.”

The requirements for ATFM as outlined in Annex 11 are supported by *ICAO Procedures for Air Navigation Services - Air Traffic Management (Doc 4444 – PANS-ATM) and ICAO Manual on Collaborative Air Traffic Flow Management (Doc 9971)*, which defines ATFM as:

“A service to facilitate safe, orderly and expeditious flow of air traffic by not only ensuring that ATC capacity is optimized and utilized to the maximum extent possible, but also allowing the traffic demand to be compatible with ATC capacity”

In essence, ATFM is an overarching concept that reflects the solutions to balance the demand on the ATM resources with the available capacity to accommodate that demand. It is important to note that ATFM does not generate delays but rather aims to eliminate congestion caused by excess demand while, at the same time, enhancing predictability. Delays are not necessarily eliminated without a concerted capacity enhancement effort.

ATFM is implemented at differing levels of complexity globally. Some implementations are at the local level, covering primarily flights within the air navigation service provider (ANSP)’s area of responsibility such as in a Flight Implementation Region (FIR). Examples of these “domestic” implementations are in the United States, Japan, and Australia; each with customised automated demand-capacity balancing systems to suit their needs. Other implementations are at the regional level with a single regional ATFM centre providing the service for the region. This is the case in Europe, with EUROCONTROL Network Manager providing the ATFM service for the European airspace network. In recent years, a new concept of a regional distributed cross-border ATFM network has also been explored and implemented, in which the ANSPs in the region are each responsible for demand-capacity balancing within their areas of responsibilities but are connected with each other on a network of efficient ATFM information exchange. This interconnectedness, coupled with common ATFM operating principles adhered to by the network members, allows for cross-border ATFM operations affecting transboundary flights without the need for a single regional ATFM centre. This concept has been implemented in Asia-Pacific under the APAC Cross-Border Multi-Nodal ATFM Collaboration (AMNAC) and in Latin America and the Caribbean under the CANSO ATFM Data Exchange Network for the Americas (CADENA) initiatives. It is also being explored in the Middle East and may eventually become the concept that enables a globally interconnected ATFM network.

ATFM Basics

1.2 How is ATFM executed?

ATFM Phases and Measures

The ICAO Manual on Collaborative ATFM (Doc 9971) identifies that ATFM activities should be carried out in three operational phases - **Strategic ATFM, Pre-Tactical ATFM,** and **Tactical ATFM**. The ATFM solutions that fit into these phases can differ between States/ANSPs depending on their operational environments. The focus of the operations in these phases is in balancing traffic demand with the available capacity of an ATM resource, which is a function of airspace/airport design and complexity, technical infrastructures such as communications, navigation, and surveillance systems, ATC staffing defined by workload, training, and capability, and meteorological conditions among other factors.

Strategic ATFM is defined as actions carried out more than one week prior to the day of operations and includes activities such as airline scheduling, airport slot coordination, performance prediction, and capacity analysis.

Pre-Tactical ATFM is defined as actions taken one day to one week before the day of operations with key activities including the development of ATFM Daily Plans that communicate planned or expected ATFM solutions such as conditional route availability based on the Flexible Use Airspace (FUA) concept, airspace re-sectorisation, or ATFM measures in anticipation of the expected demand.

Tactical ATFM is defined as actions taken on the day of operations.

Table 1 below highlights a number of measures, as identified in the Manual on Collaborative ATFM (Doc 9971), that could be used to help manage the demand-capacity imbalance in the ATM system and the resource constraints that could be addressed.

Table 1 - Air Traffic Flow Management Measures (ICAO Doc 9971)

ATFM Measure	Constraints addressed	Description
Ground Delay Programme (GDP)	• Airport Arrivals • Airport Departures • Airspace	A ground delay programme is a process where aircraft are held on the ground in order to manage capacity and demand in a specific volume of airspace or at a particular aerodrome. It aims primarily to reduce airborne delays. GDPs can be considered both pre-tactical and tactical.
Ground Stop (GSt)	• Airport Arrivals	Ground stops are taken in reaction to unpredicted adverse situations. Alternative ATFM measures should be explored prior to GSt implementation due to significant impact on delay propagation through the air transport network.
Minimum Departure Intervals (MDI)	• Airport Arrivals • Airspace	Minimum departure intervals are applied by setting a rate of departure flow between successive departures from a single aerodrome. They are typically applied for short periods to assist with short term demand/ capacity imbalance.

ATFM Basics

1.2 How is ATFM executed?

ATFM Phases and Measures (continued)

ATFM Measure	Constraints addressed	Description
Fix Balancing	• Airport Arrivals • Airspace	Fix balancing is usually applied during flight and aims to distribute demand by assigning a different arrival or departure fix than that indicated in the flight plan.
Level Capping	• Airspace	A level cap is a flight level restriction to limit aircraft climb or descent.
Minutes-in-Trail (MINIT)/ Miles-in-Trail (MIT)	• Airport Arrivals • Airspace	MINIT/MIT are expressed as the number of minutes or miles between successive aircraft in an airspace boundary point. Regular use of MINIT/MIT may suggest that more appropriate ATFM measures should be in place due to the high controller workload and potential upstream effects.
Re-Routing	• Airspace	Re-routing is usually applied to ensure that aircraft operate with a required flow of traffic, remain clear of constrained airspace, and avoid areas of known weather conditions.

The tactical measures discussed aim to minimise potential demand-capacity imbalances by providing alternative actions to manage delays and improve predictability for all stakeholders in the network.

ATFM Basics

1.3 ATFM Concept of Operations

ATFM is implemented differently in various parts of the world, reflecting the various geography, geopolitics, and operating environments in which States/ANSPs operate. Three main models of ATFM have been implemented to date – **domestic, regional-centralised, and regional-distributed;** the models are discussed in more detail in *ICAO Doc 9971*. This section provides how these models are used in different parts of the world.

Domestic/National ATFM Concept

United States

The first ATFM model is the domestic or national ATFM concept, focusing primarily on domestic traffic managed by a single ANSP or entity. A prime example of this model is the ATFM operation used by the Federal Aviation Administration (FAA) of the United States.

In the US, the FAA oversees a large proportion of the globe's airspace with large oceanic airspace on either side of the country, allowing for the flexible handling of enroute traffic around constraints such as weather. ATFM in the US National Airspace System (NAS) is primarily applied at major airports and in the surrounding terminal airspace to manage constraints and congestion caused by bad weather, traffic overloads, and emergency situations, and is managed nationally by the *Air Traffic Control System Command Center (ATCSCC)*. The US ATFM system is primarily made up of Airspace Flow Programmes (AFP) and Ground Delay Programmes (GDP), known collectively as Traffic Management Initiatives (TMI). GDPs and AFPs are managed by the distribution of Estimated Departure Clearance Times (EDCT) to aircraft subjected to the ATFM measure[1]. GDPs focus on allocating ground delays to flights that are destined for congested or capacity-constrained airports, thereby holding them at their airport of origin to help reduce the amount of fuel consumption that would otherwise be required through airborne holding at the destination. AFPs work in a similar way by allocating EDCTs to flights destined for severely congested or weather-affected airspace. Other tactical ATFM measures such as minutes-in-trail, miles-in-trail, level capping, and re-routing are also used, as well as occasional airborne holding when the delays per aircraft are expected to be minimal.

The FAA ATCSCC conducts ATFM using a tool called the *Flight Schedule Monitor (FSM)* to monitor airport demand-capacity balances, model ATFM initiatives, and evaluate ATFM alternatives. GDPs are modeled in the FSM software and arrival slots are allocated to aircraft based on identified capacity and flight times. The FSM creates a collaborative environment between the ANSP (FAA) and airspace users, and supports the collaborative trajectory options programme which allows airspace users to add preferences for potential re-routing and delay options.

Australia

Another example of a domestic ATFM model is implemented in Australia and managed by Airservices Australia. Airservices Australia serves two FIRs, collectively making up 11% of the world's airspace. In Australia, the aeronautical information publication (AIP) Enroute Supplement Australia (ERSA) defines the ATFM phases as strategic, generally occurring more than one day prior to day of operations, pre-tactical occurring on the day prior to operations, and tactical occurring on the day of operations. Key ATFM activities in Australia include strategic planning facilitated by slot coordination through the independent Airport Coordination Australia (ACA), pre-tactical planning through the planning and implementation of the ground delay programme managed by the Airservices Australia Network Coordination Centre (NCC), and aircraft sequencing facilitated by air traffic controllers and dedicated ATM systems at key airports during the tactical ATFM phase.

[1] EDCT is similar to the Calculated Take-Off Time (CTOT), which is the term used in Doc 9971 to refer to a take-off slot assigned to aircraft subjected to the Ground Delay Program (GDP).

ATFM Basics

Domestic/National ATFM Concept

Australia (continued)

The two key ATFM systems used in Australia are *Harmony* and *MAESTRO*. *Harmony* facilitates Ground Delay Programme requirements and *MAESTRO (Means to Aid Expedition of Sequenced Traffic with Research of Optimisation)* supports arrival management.

Harmony software monitors demand-capacity imbalances across the Australian airspace network and implements an ATFM measure (GDP) when required. Key information such as runway availability, forecast conditions, and airport acceptance rates are used to determine airport capacity, while traffic demand is determined through real-time updates to schedule data via flight plans and surveillance data. Any demand that exceeds the determined capacity is then converted into ground delays in the form of a Calculated Take-Off Time (CTOT). *Harmony* currently allows airspace user collaboration through the Enhanced Substitution Module (ESM), which allows airspace users to optimise their fleet utilisation through internal slot swapping and external slot exchange functionality through a web client.

MAESTRO is an estimated time of arrival (ETA)-based software that calculates the arrival sequence for flights into key airports using key information such as flight position and speed, runway operation mode, meteorological conditions, and airport acceptance rates. Information from *MAESTRO* is then utilised by controllers for sequencing activities including speed control, vectoring, or airborne holding to achieve safe and orderly arrival traffic flow into the airport.

Regional-Centralised ATFM Concept

The European ATFM network is an example of a regional-centralised ATFM system. The concept arises from a dense set of national ATM systems that provides limited flexibility when dynamic flow management is required to avoid congested sectors. The European ATFM network is made up of high-level airspace management by *EUROCONTROL's Network Manager Operations Centre (NMOC)* and national-level airspace management by individual ANSPs; with solutions typically comprising complex combinations of ground holding and airborne holding to balance between the efficiency of operations and equity of delay distribution.

At NMOC, key activities during the ATFM phases include strategic planning through the development of a Network Operations Plan (NOP) and pre-tactical planning with a focus on collaborative decision Making (CDM) with all airspace users, culminating in ATFM Daily Plans or Initial Network Plans being communicated through an industry portal. Subsequently in the tactical phase, collaborative flow management planning is executed by EUROCONTROL, resulting in the tactical application of ATFM measures known as slot allocations. Slot allocations - in the form of *Calculated Take-Off Times (CTOTs)* - are issued to airspace users whose planned flights are expected to transit constrained or congested airspace, thereby distributing the demand more evenly throughout the network.

The key facilitating system for ATFM used by EUROCONTROL Network Manager is the *Enhanced Tactical Flow Management System (ETFMS)*. The ETFMS has two key functions: the assessment of flight plan information and the calculation of traffic demand for every sector in the Network Manager's area of responsibility; and the computer-assisted allocation and distribution of ATFM slots (CTOTs) to all participating airspace users. The ETFMS utilises flight activation and monitoring, and flight profile calculation functions to accurately assess demand-capacity imbalances and to allocate the ATFM slots, with the aim of reducing potential airborne delays in the congested airspace.

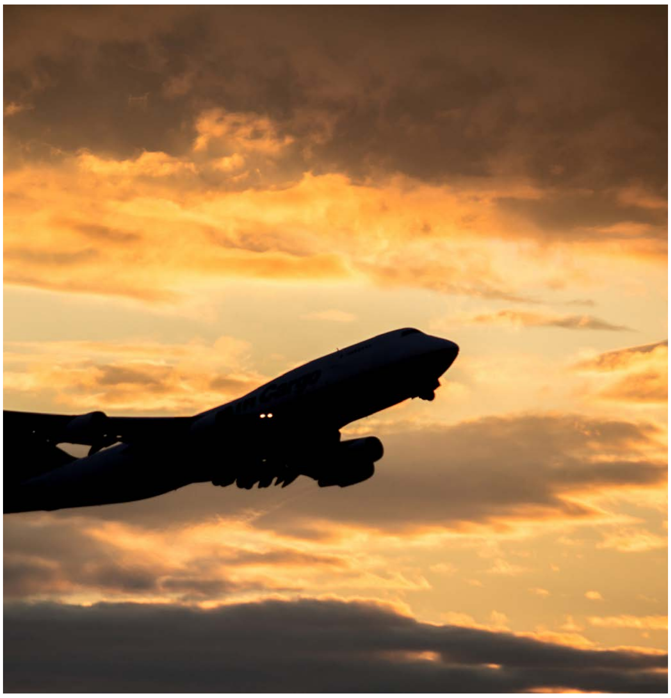
ATFM Basics

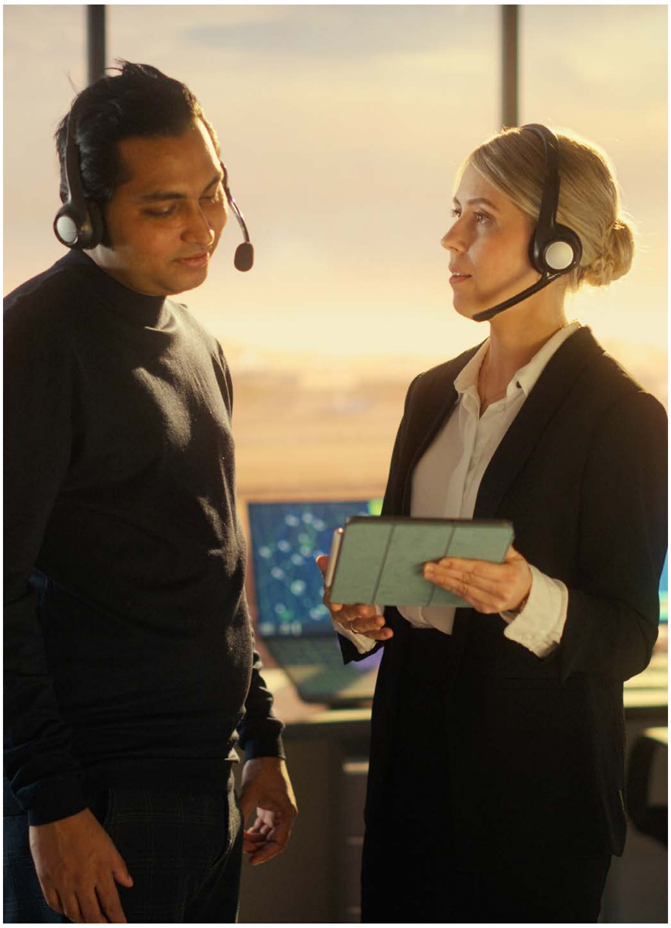
Regional-Distributed ATFM Concept

In places where a region-wide agreement for a centralised ATFM centre such as EUROCONTROL Network Manager is not possible, a different ATFM concept has emerged. This is known as the regional-distributed ATFM concept, which is employed in parts of Asia-Pacific and (separately) Latin America and the Caribbean and is also being evaluated for regional implementation in the Middle East. The concept, first introduced in Asia-Pacific as the *Distributed Multi-Nodal ATFM Network* concept, is based on a network of ANSPs leading independent ATFM operations within their areas of responsibility and connected to other ANSPs and stakeholders through effective information sharing and collaborative decision-making mechanisms. This is achieved with two operational bases:

- *Common Operating Procedures* that guides how cross-border ATFM measures – such as a Calculated Take-Off Time (CTOT) distribution in a Ground Delay Programme (GDP) – are to be used within the network; and
- *An Interconnected Information Sharing Framework* that establishes mechanism and protocols for efficient ATFM information exchange among stakeholders in the network, thereby allowing key information – such as CTOTs – to be delivered to the right place and at the right time for effective compliance facilitation.

These operational bases allow an ANSP to independently implement ATFM measures to manage both domestic and international traffic into resources where demand is exceeding capacity within their area of responsibility, while other ANSPs and stakeholders in the network can effectively comply with the measures based on the common operating procedures. This concept therefore removes the requirement for a centralised ATFM unit providing the service for the entire region but retains ANSPs' independence in managing their own ATM resources; a concept suitable for several regions' geopolitical environments.





Existing Approaches and Trials

This chapter explores the existing approaches to Long-Range ATFM and ongoing trials to implement the concept around the globe.

2.1 Existing Approaches

While Long-Range ATFM (LRATFM) is a relatively new area, a few approaches exist today that can be categorised as the basis for an early form of LRATFM. Two examples of such approaches are introduced here.

Bay of Bengal Cooperative ATFM System (BOBCAT)

The Bay of Bengal Cooperative ATFM System (BOBCAT) is one of the earliest international LRATFM initiatives, having been in operation since 2007. The system was borne out of traffic management requirements for the Afghanistan airspace (Kabul FIR), which was one of the busiest gateways for westbound traffic from South/Southeast Asia to Europe/North America.

Due to night curfews in effect at most European aerodromes, most of the westbound traffic from South and Southeast Asia to destinations in Europe are flown overnight, rendering the hours between 2000 – 2359 UTC (Universal Time Coordinated) a peak period for Kabul FIR. Due to political instability and conflicts in the area in the early 2000s, however, Kabul ACC (Area Control Centre) had to operate under constraints. Consequently, the ATS (Air Traffic Services) route and flight level availabilities in Kabul FIR were limited. To cope with the limited physical capacity, Kabul ACC had to also impose extended procedural longitudinal spacing on the routes, further exacerbating the capacity limitation and rending it insufficient for the peak traffic hours.

Recognising the insufficiency of capacity available, Asia-Pacific ANSPs through the ICAO Asia/Pacific Regional Office's ATFM Task Force and airlines under the leadership of the International Air Transport Association (IATA) discussed and agreed on the need for an automated ATFM system to help smooth the flow of traffic through the available ATS routes with the flight level limitation and spacing requirements. The discussion resulted in the creation of the **Bay of Bengal Cooperative Air Traffic Flow Management (BOBCAT)** arrangement, which was first put in operation in July 2007.

Under the BOBCAT arrangement, AEROTHAI – through the Bangkok ATFM Unit – allocates ***(ATFM) slots*** to westbound traffic intending to transit Kabul FIR between 2000 – 2359 UTC nightly. The allocation of slots would be based on advance requests by the airlines and an optimisation algorithm to ensure minimum ATFM delays while satisfying all airspace conditions. Each allocated slot consists of:

- **Calculated Take-Off Time (CTOT)** from departure aerodrome,
- **Assigned waypoint** to enter Kabul FIR and associated ATS route to transit the airspace,
- **Calculated Time Over (CTO)** the assigned waypoint, and
- **Assigned flight level** for airspace transit.

The ATS routes for which BOBCAT ATFM slots are allocated are listed in the AIP-Afghanistan (ENR1.9) and are replicated in other affected States' AIPs including AIP-Thailand (ENR 1.9).

Under this arrangement, an Airspace User wishing to operate a flight through Kabul FIR between 2000 – 2359 UTC on the ATS routes included in this arrangement should lodge a BOBCAT Slot Request via the Bangkok ATFM Unit's BOBCAT System *before 1200 UTC* on the day of operation. Once all the requests have been lodged by 1200 UTC, BOBCAT System will automatically allocate the slots and, after a review by Bangkok ATFM Unit, distribute them to the Airspace Users and relevant ANSPs responsible for the departure aerodromes. If an airspace user is unable to lodge a slot request before 1200 UTC or is not satisfied with the allocated slot, the airspace user can log into the BOBCAT System to select a new slot from the remaining available ones using the system's web interface. Upon obtaining satisfied slot allocation, a flight plan can then be submitted in accordance with the slot received.

Existing Approaches and Trials

Bay of Bengal Cooperative ATFM System (BOBCAT) (continued)

Throughout its long-running history, the BOBCAT operation has been proven beneficial for stakeholders involved as is evidenced by an IATA estimation of over 160 million kilograms of fuel-saving from the programme. The operation has been an essential part of air traffic management provision in the Afghanistan airspace, especially during the height of the regional conflict. Fortunately, the conflict has been de-escalating and Afghanistan's airspace infrastructure has been improving, resulting in a continual reduction of ATFM delays in recent years. Nevertheless, until the service is no longer needed or an alternative means of LRATFM for this area becomes available, BOBCAT will continue to remain operational.

Despite the benefits shown, however, the BOBCAT operation is not perfect. As a well-established regional ATFM programme, departure compliance to BOBCAT-allocated CTOTs has been satisfactory with average compliance of over 70%. On the contrary, though, compliance to BOBCAT-allocated CTOs at Kabul FIR entry waypoints has been significantly lower with many flights consistently arriving at the FIR gateway earlier than their assigned slots. This signifies the high variability in long-haul flights' operating times as they transit many FIRs along the way, often rendering planned flight times calculated far in advance inaccurate. Reasons for the inaccuracies can range from imperfect enroute weather prediction and flight planning to tactical ATC (Air Traffic Control) instructions along the way. This inaccuracy and non-compliance contribute to a reduced effectiveness of the programme overall.

As BOBCAT had been designed in response to "static" and "strategic" airspace requirements (i.e., specific ATS route and flight level availability and pre-defined spacing requirements) as opposed to "dynamic" and "tactical" constraints, the operation – which may be more aptly described as a "pre-tactical" LRATFM – does not include several features thought to be essential for effective "tactical" LRATFM operation. These features include active flight following and tactical adjustments in response to the changing behaviors of the flight enroute, and the tactical air-ground ATFM data exchange. Developing and incorporating these features into an ATFM operation is the next step in the LRATFM concept development. While that is happening, BOBCAT will retain its place as an early contributor to this evolution of ATFM.

NATS Extended Arrival Management (XMAN)

The Extended Arrival Management (XMAN) is an ATFM solution that was introduced to extend arrival management coordination beyond the current AMAN (Arrival Management) target areas to allow for earlier sequencing of arrival traffic. The conventional AMAN target area is usually a range of 40-50 Nautical Miles (NM) from an airport; the XMAN concept extends this range to 150-200 NM from an airport. The XMAN concept, which became fully operational in the United Kingdom in 2015, is a cross-border arrival management system that extends the arrival manager range out to 350NM from London Heathrow Airport. When delays at Heathrow exceed 7 minutes, the XMAN system communicates to surrounding ANSPs that inbound aircraft will need to slow down during cruise to streamline approaches into the airport. The aim of the XMAN concept was primarily to reduce the airborne holding and stack holding in the airspace surrounding congested airports. The system requires effective information sharing and communication between multiple ANSPs and FIRs with the aim of reducing fuel costs through efficient delay management during the cruise phase of flights.

Existing Approaches and Trials

2.2 Ongoing Trials

Apart from the existing approaches discussed above, several research and operational trial projects have also been carried out by ANSPs to explore the extension of conventional ATFM in order to address the limitations present such as long-range trans-regional and/or international flights being exempted from ATFM measures.

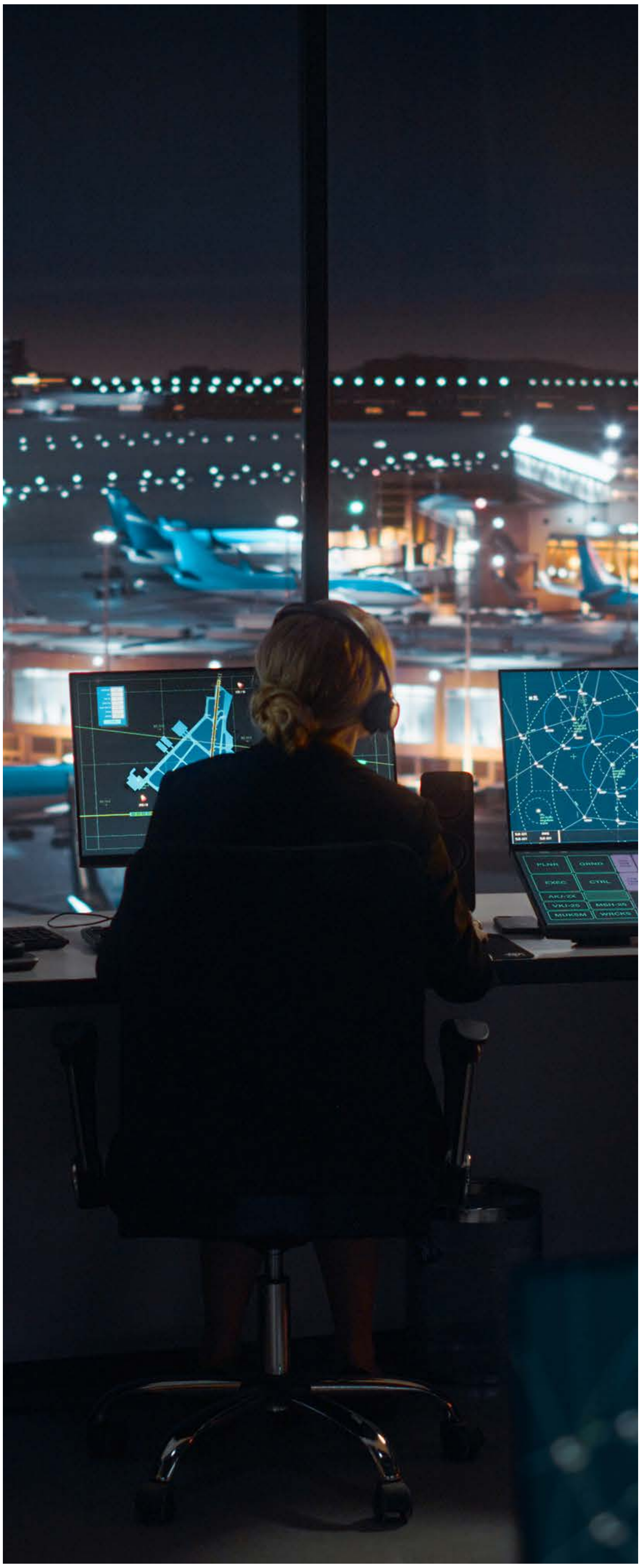
CTO Operational Trial (JANS)

In 2011, Japan's ANSP, JANS (Japan Air Navigation Services) initiated what, in hindsight, could be considered one of the first LRATFM operational trials. The purpose of the trial was to determine whether ATFM delays could be more equitably distributed among both domestic and international arrivals through the assignment of CTOs to inbound aircraft from other FIRs.

During the trial, the aircraft subject to the flow control measure was assigned a CTO at the arrival waypoint. The CTO itself was calculated by supporting software. Once calculated, the CTO was communicated to the aircraft via controller voice communication after it had entered Japanese airspace (Fukuoka FIR).

During this trial, problems were identified, which if corrected, could improve the CTO compliance rate. One such problem was the large difference between the ETO at the arrival waypoint calculated by the ATC system and the ETO calculated by the aircraft FMS. An additional problem was that during the trial, ATC had to wait to assign the CTO to the aircraft until after it had entered the Fukuoka FIR. This practice reduced the possible range of speed adjustment the aircraft could make before the arrival waypoint, which made it difficult to safely comply with the assigned CTO.

The trial is still ongoing and JANS has been upgrading the support systems as well as gathering and verifying the new system's CTO calculation data. The aim is to expand the CTO operation across the FIR boundary after implementing it within Fukuoka FIR.



Existing Approaches and Trials

Long-Range ATFM Trial Project (Airways New Zealand, CAAS, NATS UK)

In 2017, a LRATFM trial project was devised between NATS (UK), Airways New Zealand (New Zealand), and CAAS (Singapore), with the aim of providing operational research into the basic factors of a LRATFM concept and of testing the communication processes, the accuracy of time estimates, and the interaction with - and compliance of - aircraft crew. Operational trials facilitated by Airways and CAAS focused on aircraft during the enroute phase of flight using a target time over (TTO) milestone approach to manage traffic demand. Note that TTO is conceptually identical to the term *Calculated Time Over (CTO)*, which will be used in discussing the LRATFM concept in this Paper and refers to an LRATFM time slot over a specific waypoint with which an aircraft is expected to comply. In discussing the LRATFM concept trials conducted by Airways/CAAS/NATS, the term "CTO" is therefore used in lieu of TTO for consistency.

Together, Airways/CAAS/NATS developed five key phases of the trial LRATFM concept:

1. Concept users agreed to establish a flight adjustment zone within which LRATFM can be applied based on the operational environment, time estimate accuracy, communication, and compliance capability.
2. Entry into the flight adjustment zone begins at the Flight Adjustment Zone Entry Fix when a reliable Estimated Time Over (ETO) value can be used to calculate the CTO reference fix time.
3. At the Flight Adjustment Zone Entry Fix, the CTO reference fix time is communicated to the flight crew via agreed communication path.
4. Flight crew confirm their ability/inability to comply with the CTO at the reference fix to the relevant authority.
5. Flight crew adjusts the flight to reach the CTO reference fix at the CTO time or advises ATC of their inability to comply with a revised ETO.

Figure 1 below shows an adapted diagram of the NATS, Airways, and CAAS LRATFM concept.

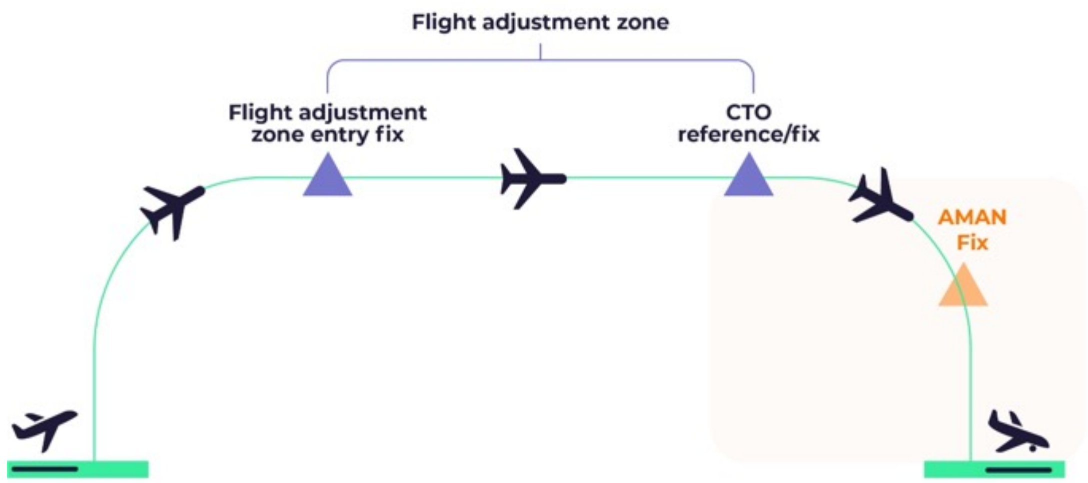


Figure 1 - NATS/Airways NZ/CAAS LRATFM Concept

Existing Approaches and Trials

Long-Range ATFM Trial Project (Airways New Zealand, CAAS, NATS UK) (continued)

The trial facilitated by Airways used an initial inbound CTO horizon of 2 hours from destination, which was chosen based on initial assumptions from the Flight Management System (FMS) and Oceanic Control System (OCS) estimate accuracy and aircraft compliance capability. The results identified that ATFM delays of 1-3 minutes per each remaining flight hour were achievable in nominal conditions, and that the most accurate trajectory estimation used for CTO allocation was achievable through the OCS ETO data. Inaccuracy of wind data was identified as a major factor for the inaccuracy of trajectory modelling and most long-haul flight planning information became increasingly inaccurate after departure due to limited or no weather data updating. The trial also identified that communication was achievable through Controller-Pilot Data Link Communications (CPDLC), and that non-participation was due to prohibitive fuel burn cost or airline scheduling requirements whereas non-compliance was related to unacceptable FMS performance calculation due to the difference between forecast and actual winds.

Separately, the trial facilitated by CAAS focused on CTO communication to the flight deck through the Airline Operation Center (AOC), with the required ATFM delay and CTO information sent to the AOC via email when the flight was within 6 hours of the CTO reference fix. The trial results identified that an ideal timeframe for ATFM delay distribution should be at least 4-5 hours prior to the aircraft reaching CTO reference fix. The CAAS trial was able to attribute approximately 4 minutes of the required ATFM delay to the enroute phase, leading to an achievable delay absorption figure of approximately 1 minute per each remaining flight hour.

Both trials provided a foundation upon which the LRATFM concept can continue development. Future work will include the exploration of alternative communication paths, the integration of existing ATFM advisory information in CTOs, cross-FIR feasibility, synchronisation with existing ATFM and arrival sequencing solutions such as GDP and AMAN, and the possibility of linking regional ATFM programmes through shared information.

Australia Long-Range ATFM Trial and Implementation (Airservices Australia)

Airservices Australia has determined that LRATFM will be implemented as an enhancement to their domestic ATFM applications. LRATFM from their perspective is an enhancement of their existing collaborative decision-making practices by extending demand and capacity management to international flights. Their LRATFM concept involves extending the point of intervention for inbound long-haul flights out to approximately 4 hours through the assignment of Calculated Time Over (CTO) at arrival waypoints. The early provision of this CTO will allow flight crews to manage delays by small speed reductions in cruise, which ‘pre-conditions’ the traffic into the tactical arrival management arena, approximately 45 minutes from arrival. The LRATFM system will track any delay absorbed and applies this as a ‘delay credit’ once the final arrival sequence is determined, during which time the long-range flights are merged with domestic traffic streams.

The Australian LRATFM concept focuses on the management of long-haul arrivals and their integration into the domestic aviation network particularly during peak demand periods at key capital city airports. The concept will make sure controls are put in place to ensure that no unnecessary delay is being assigned to long-haul flights. It is therefore essential the LRATFM process is embedded in the existing collaborative decision-making processes, to ensure capacity and demand imbalances are recognised in a timely manner and an optimal combination of LRATFM and domestic ground delay programmes are being applied. This provides the best outcome for the entire network, distributes delay equitably and maximises the utilisation of available capacity.

Why Long-Range ATFM

This chapter discusses the high-level objectives of Long-Range ATFM, and how its implementation can provide added benefits to ANSPs and their stakeholders in terms of the efficiency of airspace management and flight operations.

3.1 Long-Range ATFM Objectives

The initial LRATFM concepts explored by ANSPs were developed to solve specific problems within their ATFM systems. It is for this reason that LRATFM is often interpreted differently by different stakeholders. The understanding of what is meant by LRATFM depends on the history, expectation, and perspectives of stakeholders. Some of the most common definitions of LRATFM are:

- The application of ground holding to manage airborne demand at a constrained enroute waypoint.
- The integration of ground and airborne holding to manage arrival demand at a constrained airport. In this context, LRATFM focuses on the interplay between CTOT and CTOT-exempt flights.
- The application of dynamic routing to manage airborne demand at a constrained enroute waypoint in adverse conditions.

In Chapter 2, existing approaches and trial implementations of LRATFM were discussed in detail, each with different objectives.

In the Bay of Bengal, BOBCAT was introduced to manage air traffic flow more effectively through airspace with severe capacity restrictions. In the United Kingdom, *NATS XMAN* was developed to assist with the distribution of delays into a more fuel-efficient phase of flight and effectively sequence aircraft into congested airspace around high demand airports. Similarly, the *Airways (New Zealand)* and *CAAS (Singapore) trials* were initiated to determine if there was a concept that would enable increased predictability of long-haul arrival estimates and integrate them into current ATFM measures.

The *NATS XMAN* concept has been able to demonstrate several benefits for flights arriving at London Heathrow Airport. Benefits include a reduction in stacked airborne holding through the absorption of delays during cruise. This reduction in airborne holding has subsequently assisted with a reduction in aircraft fuel burn and provided an operational example of multi-national ANSP cooperation.

The *Airways New Zealand* and *CAAS* trials were established to develop a concept that may be able to address the limitations and ineffectiveness of their current operations. Current system limitations were resulting in low predictability of long-haul arrival estimates, over-capacity arrival flows with long-haul arrival waves, and the unbalanced allocation of delays between short-haul flights captured in the ATFM program and long-haul flights exempted from it.

The *Airservices Australia* LRATFM concept expected the outcomes to include increasing predictability of operations, orderly flows of traffic into tactical AMAN environments at major airports, equity in delay allocation across the network, and increased network performance. The concept aimed to provide efficiency, safety, and environmental benefits by reducing fuel burn, controller workload, tactical delay, and ATFM delays.

All current interpretations of LRATFM initiatives are designed to address similar problems and hope to result in similar outcomes. Key reoccurring problems usually include the equitable distribution of delays throughout the network and increased predictability of arrival aircraft to allow integration into current ATFM systems.

Why Long-Range ATFM

3.2 Definition of Long-Range ATFM

Each version of LRATFM briefly summarised above and in Chapter 2 could validly meet the literal description. We need to begin here then by defining the concept of LRATFM used in this White Paper.

The reason for creating the LRATFM concept is to describe the way in which multiple elements of ATFM and various ATFM solutions in the pre-tactical and tactical timeframes can be merged into a single workflow.

For this white paper, LRATFM is therefore defined as a subset of ATFM to meet this requirement:

"The integration of ATFM solutions to deliver a collaboratively balanced flow of long-haul and short haul aircraft to an ATM resource (airport, waypoint, or a sector of an airspace)."

Collaborative data and/or information exchanges between ANSPs and airspace users are critical in identifying demand through airspace or impacted airports to help identify the need for LRATFM. The establishment of two-way data/information exchanges between ANSPs and/or ANSPs and flight operators increases the situational awareness of all participants in LRATFM and provides for collaborative decision making with the most accurate information available.

3.3 Potential Benefits of Long-Range ATFM

Well-implemented LRATFM can provide added benefits to ATM operations and the environment. Below are some potential benefits:

Predictability

Improved data sharing between airspace users and ANSPs, along with integrated decision support tools, can help to manage demand around key constraint points in the affected airspace or airport. The improved data sharing also allows for greater adherence to flight schedules. The well-managed demand and schedule adherence delivers improved predictability of aircraft movement on the day-of-operation.

Equity

Distribute delay among all airspace users rather than forcing only local or regional airspace users to account for most of the required delay. This also allows for the delays to be spread across a larger number of flights, thereby reducing the delay assigned to each individual flight.

Environmental Efficiency

More efficient end-to-end times will decrease the overall miles flown by reducing vectoring and airborne holding. This will lead to less fuel burn and a smaller carbon footprint for every flight.

Reduced Fuel Costs

More reliable end-to-end aircraft times provide airspace users more opportunities to make better business decisions concerning fleet management and fuel loading.

Enhanced Safety

The ability to plan for demand in a sector of airspace reduces controller workload and enhances safety. Aircraft will arrive at an airspace or airport where demand is exceeding capacity in an efficient and controlled manner, thereby reducing complexity and enhancing safety.

Why Long-Range ATFM

3.3 Potential Benefits of Long-Range ATFM (continued)

Airspace Efficiency

Increased predictability on the day-of-operations allows flights to absorb delays caused by merging and sequencing in a more fuel-efficient manner. For example, delays that are typically absorbed via holding, low-altitude vectors, excessive speed control and long down-winds in the current system will be shifted further upstream and absorbed via more efficient means such as speed-control, vectors at higher altitudes, or controlled time of departure at the airport of origin.

Surface Management Efficiency

By having a controlled time over an enroute fix or at an arrival airport, an associated controlled time of departure can be determined, which will lead to more efficient surface flows and reduced wait times in physical departure queues at departure airports. Gate holds can be used instead of extended taxi times to help manage the departure flow and surface congestion more efficiently.

Reduced ATC Workload

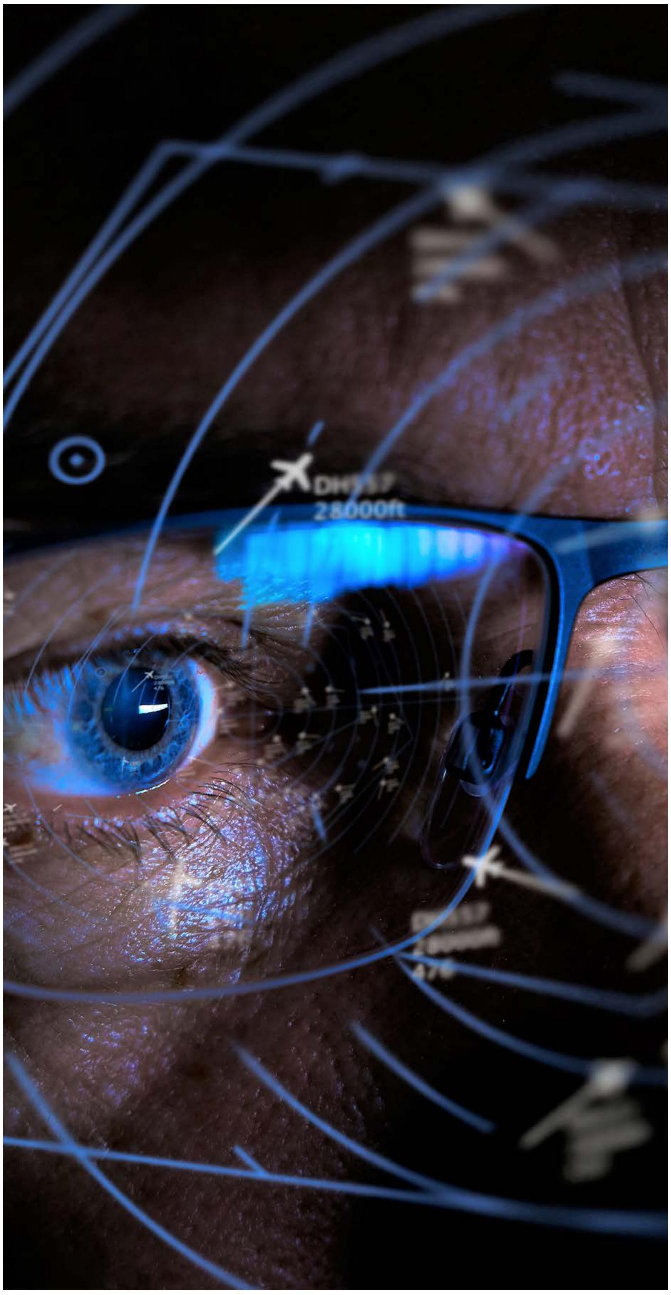
Unplanned or no-notice holding, excessive speed control, and vectoring are workload intensive and can distract ATCOs from performing other critical tasks. LRATFM is one of many ATFM solutions which can facilitate an orderly flow of traffic that can be managed safely and efficiently.

Dynamic Use of Airspace

Demand and capacity imbalances can be identified and ATFM measures implemented to avoid congested or weather impacted areas. ATC's vectoring of aircraft off their planned routes can be reduced, and protection of airspace in case of airborne holding is minimised, allowing for a more efficient usage of the airspace on a regular basis. Increased availability of airspace can enhance the opportunities for airspace design that will facilitate continuous descent operations wherever possible.

Flight Planning Flexibility

LRATFM, in conjunction with Airport-Collaborative Decision Making (A-CDM), can enable increased collaboration regarding airspace user trajectory preferences, and can help shape customised, business-friendly solutions to airspace and airport constraints. The increased emphasis on strategic planning and the capability for airspace users to submit flight preference information means more flexibility for airspace users in how constraints are managed.



Proposed LRATFM Concept

This chapter proposes a high-level concept of Long-Range ATFM and how it can be implemented under a "perfect" environment. The proposed concept and scenario can be used as a basis for developing real-world concept of operations and implementation plan.

4.1 Conceptual Approach

The development of a LRATFM concept should address the unique challenges of the operational scenario it aims to benefit. As discussed earlier in this paper, it is not a trivial problem as is evidenced by the many trials that have been conducted, none of which have yet led to a successful large-scale operational implementation.

Rather than attempting to provide a detailed concept which is likely not to fit the different operational challenges, this chapter first provides what the LRATFM scenario could be if implemented in a *"perfect world"*.

The *"perfect world"* scenario has all the real-world complexity removed, allowing the concept to be simply described. While the perfect LRATFM scenario may be difficult to achieve, applying this top-down approach ensures that when addressing individual challenges, the focus remains on the outcome LRATFM aims to achieve.

The subsequent chapter, Chapter 5, then discusses several challenges that should be considered and addressed when developing a viable implementation model that is tailored to a specific environment, based on the perfect-world scenario proposed in this chapter. The *tailoring* of the implementation model should be based on local requirements, intended benefits, a technological baseline, and available resources to ensure it is realistic and scalable.

4.2 The Perfect LRATFM Scenario

In this perfect LRATFM scenario, a capacity and demand imbalance has been identified at an aerodrome or sector of airspace several hours in advance, requiring ATFM solutions to be implemented.

Not-yet departed inbound aircraft will be subject to a Ground Delay Programme (GDP), and inbound aircraft already airborne will be subject to a LRATFM solution. A combined ATFM programme, generating Calculated Take-off Times (CTOT) and Calculated Times Over (CTO) will be facilitated by a tool to assign required delays to both airborne and on-ground aircraft.

The amount of delay that can be allocated to airborne aircraft through LRATFM is restricted to what can be realistically achieved through speed reduction for the remainder of the flight.

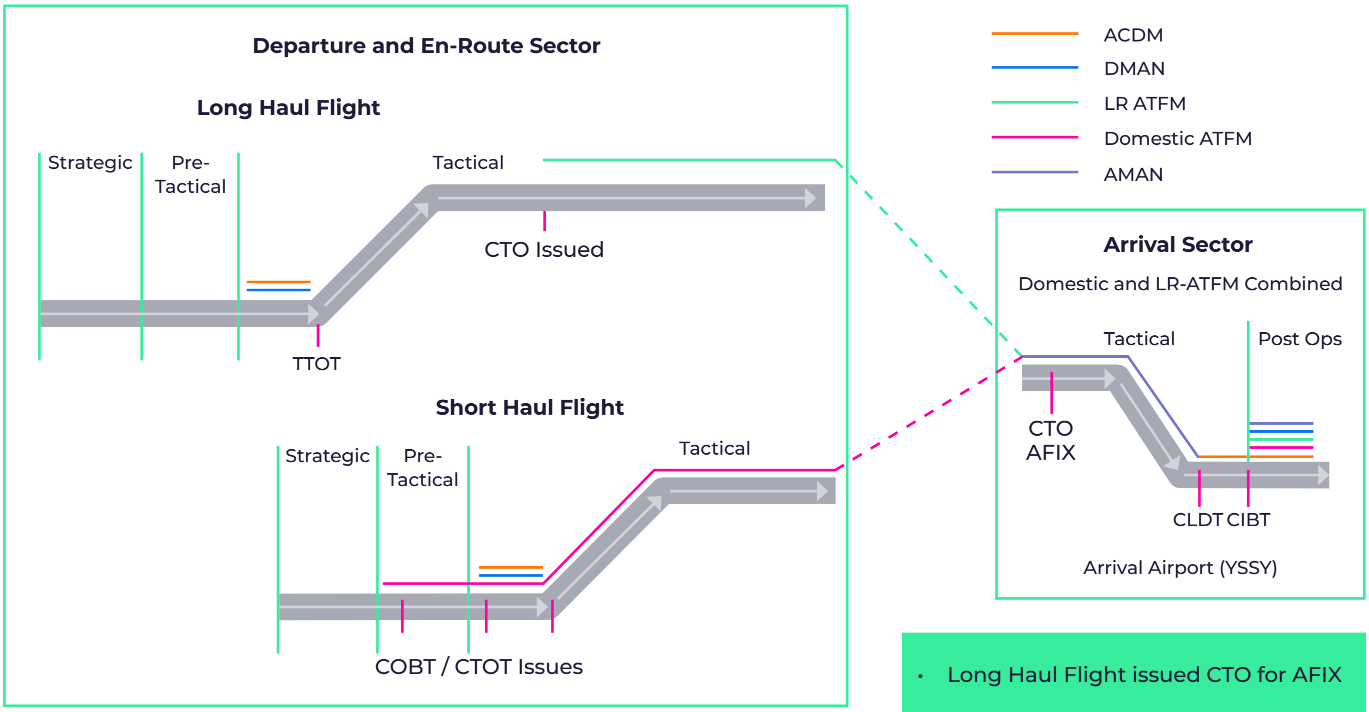
For these aircraft, the CTO with which to comply when passing over a downstream waypoint will be sent from the issuing ATFM authority to the ATS units that have jurisdiction of the aircraft, ideally through technological infrastructure based on the System-Wide Information Management (SWIM) concept. The CTO is subsequently passed to the flight crew by ATC using VHF/HF or Controller-Pilot Data Link Communications (CPDLC). The flight crew will then adjust the cruise strategy to meet the CTO.

By applying the LRATFM solution, the flow of long-haul aircraft managed by CTO is now being *pre-conditioned* prior to arrival. Together with the flow of short-haul aircraft managed by the GDP, the combined flow of aircraft into the tactical arrival management arena should now closely match the acceptance rate at the aerodrome. This means the need for ATC to assign significant additional airborne delays to match the runway acceptance rate should be rare and most aircraft should be able to progress towards landing with minor delays while conducting an efficient descent.

Proposed LRATFM Concept

4.2 The Perfect LRATFM Scenario (continued)

The application of this perfect world solution will meet some challenges in implementation. The next chapter discusses key challenges that will need to be overcome to successfully implement a LRATFM solution in a real-world environment.



- Long Haul Flight issued CTO for AFIX
- Short Haul Flight issued CTOT
- ATFM AAR = AMAN AAR

Figure 2 - Perfect LRATFM Scenario

Conceptual Considerations and Implementation Recommendations

This chapter discusses key considerations to address the challenges in bringing the "perfect" Long-Range ATFM concept and scenario from the previous chapter into real-world operations. This chapter also provides generic recommendations for when an ANSP/regional group is implementing LRATFM and techniques to manage the implementation cost.

5.1 Conceptual Considerations

The previous chapter discusses the LRATFM concept and provides a high-level "perfect" LRATFM scenario. Translating such a high-level concept and scenario into real-world operations will not be without challenges. These challenges can be grouped under four key areas of consideration.

Holistic Solution

LRATFM should be applied as part of a holistic ATFM solution, rather than as an isolated ATFM measure.

- Before considering the implementation of LRATFM to help balance demand and capacity in a congested area, an effort should always be made to determine if the capacity of an ATM resource (i.e., the aerodrome or an airspace sector) can itself be increased. This is especially true in the case of the LRATFM process since more lead time may be available to increase the capacity to match the expected demand.
- If after an initial analysis, the benefits of a LRATFM solution are still determined to be necessary and beneficial, the LRATFM solution should only be considered as one of the many ATFM solutions available to an ATFM Unit to holistically balance demand and capacity at a given ATM resource. To that end, the LRATFM solution should not be used in isolation when other ATFM solutions, such as a GDP for short-haul aircraft, could also be applied.
- The application of ATFM solutions, including LRATFM, should consider equity of access to the resource where demand is exceeding capacity. Delays should therefore be fairly and appropriately shared between airspace users requiring access. For example, a GDP affecting short-haul aircraft should be used in conjunction with LRATFM solution affecting long-haul aircraft, with delays apportioned to both groups of traffic equitably.

Conceptual Considerations and Implementation Recommendations

5.1 Conceptual Considerations (continued)

Achievable Delay Allocation

ATFM delays issued should be realistic, achievable, and lead to efficient operations.

- The extent of an ATFM delay assigned to an aircraft as part of an LRATFM solution should correspond to the time that the aircraft can efficiently absorb in the remaining cruise phase of the flight. This is because an airborne aircraft has a limited capability to efficiently absorb a delay, and that capability depends on – inter alia – the aircraft type, flight profile (cost index), operating procedure, and weather conditions. As a general rule, two minutes of delay per flight hour can be realistically absorbed by an aircraft in flight.
- Consideration should be given as to whether all allocated delays are issued at once, since it is likely the capacity and demand situation will continue to evolve as an aircraft progresses on its journey. Therefore, the allocation of too much delay too early should be avoided to reduce the impact to an aircraft's on-time performance.
- The horizon at which LRATFM delay is allocated should consider the accuracy of demand prediction and operational capacity declaration at that point in time. Effort should be made to prevent the allocation of LRATFM delay that proves to be unnecessary when the aircraft is approaching the point of demand and capacity imbalance. Before an ATFM measure is implemented the accuracy of the demand predictions and capacity analysis should be carefully considered, so as to either not over or under allocate delay.
- The mix ratio of short and long-haul aircraft within an area (airspace sector or airport) will affect the accuracy of any demand prediction. Typically, time estimates for an airborne aircraft are more accurate than for an aircraft still on the ground at the departure point. This can add complications to the demand prediction. Where A-CDM processes are established or surveillance exists, estimate updates and actual departure information, such as Target Take-Off Time (TTOT) and Actual Take-Off Time (ATOT), can assist. In addition, an ATFM unit intending to allocate delays to long-haul aircraft should employ a system that continually calculates and updates aircraft trajectories to ensure accurate demand predictions.
- The planning horizon for LRATFM may be limited by the size of the airspace over which an ANSP has jurisdiction unless the information is shared with upstream ANSPs.

CTO Assignment

LRATFM delays should be issued as a CTO at a specific fix rather than as speed advisory.

- Using speed advisories for enroute aircraft for LRATFM purposes should be avoided. Instead, LRATFM delays should be issued as a specific assigned aircraft time (Calculated Time Over: CTO) at a specific fix. The use of CTO allows for flight crew discretion on how the allocated delay can be safely achieved.
- The flight crew shall advise the ANSP of speed changes in accordance with ICAO PANS-ATM (Doc 4444) when adjusting the flight profile in response to LRATFM assignments.
- To avoid complicated ANSP jurisdiction matters across FIR boundaries, consideration should be given to providing LRATFM delays as advice rather than as directives. It may also be beneficial to provide an incentive to encourage flight crews to comply.
- ATC should be allowed discretion to manage the delay to prevent operational issues and to ensure adequate separation. For example, the ATC may choose to adjust the aircraft track rather than allowing a speed adjustment.

Conceptual Considerations and Implementation Recommendations

5.1 Conceptual Considerations (continued)

LRATFM and AMAN Integration

If the LRATFM area overlaps with the AMAN area, the integration of LRATFM and AMAN is desirable; but not mandatory.

- Final runway landing slot allocations as part of tactical Arrivals Management (AMAN) should be, where possible, consistent with the LRATFM solution to ensure a predictable transition for the airspace user and to avoid/minimise the assignment of multiple, possibly unnecessary delays.

5.2 Implementation Considerations

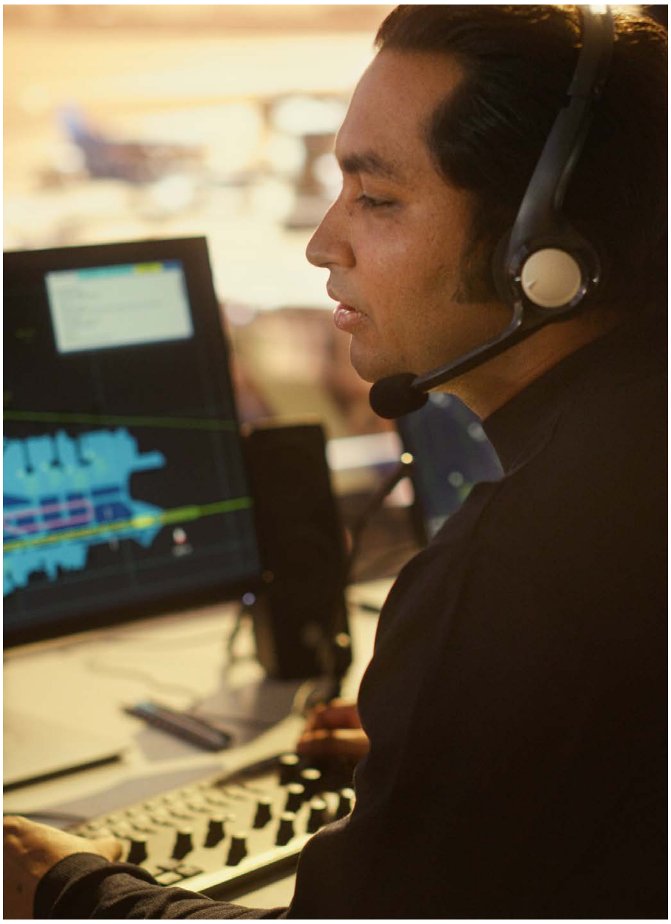
The implementation of LRATFM will not be without challenges. This section discusses some key considerations for ANSPs and/or ATFM groups when considering the implementation of LRATFM.

Stakeholder Engagement

Stakeholder engagement is at the core of every successful ATFM implementation. ATFM is a collaborative process, requiring ANSPs and airspace users to work together to achieve the optimised use of ATM capacity. This is especially true for LRATFM, since LRATFM operations will broaden the scope of the "conventional" ATFM horizon to beyond the national and potentially even beyond the regional boundary. When a LRATFM measure, such as a CTO, will be delivered to an airborne aircraft several hours and multiple FIRs away from its destination, the support of both the airspace user and the enroute ANSPs controlling the flight will be required for effective compliance. In areas where regional ATFM collaboration has already been established, the extended engagement may be carried out through the regional ATFM group/governing body and may involve ICAO or IATA.

Beyond ANSPs, LRATFM will also change the way stakeholders interact with ATFM measures. For example, trans-regional flights, previously exempted from an ATFM measure, may be asked to comply with a CTO as part of the LRATFM operation. This will require clear procedure development and personnel training for the airspace users, which means they should be engaged and included in the implementation effort from the beginning.

The introduction of LRATFM will undoubtedly change existing ATFM procedures; it is therefore of vital importance that all stakeholders are engaged early and are included in the design of the operational framework and procedures.



Conceptual Considerations and Implementation Recommendations

5.2 Implementation Considerations (continued)

Predictability

At the core of every effective ATFM solution is traffic demand and resource capacity information. Accurate prediction of traffic demand and resource capacity plays a crucial role in determining the appropriate ATFM solutions and associated parameters. In the LRATFM environment, the requirement for accurate prediction of demand and capacity remains relevant, albeit with additional challenges.

One of the primary benefits of the LRATFM concept is an ANSP's ability to prescribe an ATFM measure, such as a CTO, early in the duration of an airborne flight; thereby giving the flight crew the greatest flexibility in choosing the most optimal way to comply without undue abrupt changes to flight profile. This enhanced situational awareness for the flight crew can mean significant savings in fuel and operating cost for the airspace users.

Prescribing an ATFM measure early, however, is predicated on highly accurate, predictive traffic demand and resource capacity forecasting. In some cases, this may require an ANSP to predict their demand/capacity imbalance many hours in advance so they can provide the CTOs to the affected flights with enough lead-time for them to adjust their profiles for compliance. Such early predictions may be inaccurate – if not impossible – in some areas of the world, due to volatile weather patterns. In the absence of accurate and reliable weather forecasts, attempts to predict demand/capacity imbalances far in advance may inadvertently result in frequent changes to ATFM measures, consequently reducing the predictability provided to the airspace users rather than improving it.

In adopting LRATFM operations, ANSPs should therefore aim to balance between making early ATFM decisions for maximum predictability and the desire to retain stability in the decisions made. Engagement with stakeholders, especially airspace users, will be important to find a reasonable balance point that benefits all stakeholders.

Data Quality

Providing predictability to stakeholders through a well-prepared ATFM measure relies on high quality demand and capacity data. This can be a challenge for LRATFM, as decisions must be made well in advance and the accuracy of available data for decision-making may not be high. For example, the trajectories of long-haul flights can vary greatly over the duration of their journeys, and this can make it very difficult for an ANSP to accurately predict traffic demand values.

Similarly, ATM capacity, which can be impacted by unforeseen circumstances such as weather, can also change rapidly.

In implementing LRATFM, an ANSP should therefore be able to determine the appropriate level of data quality required to support the operations. It is worth noting that ATFM measures are inherently pre-tactical/tactical planning measures with the aim of ensuring balance between traffic demand and ATM capacity. They are not traffic separation/sequencing tools which is the case for Arrival Management (AMAN) or Extended Arrival Management (XMAN) operations. The accuracy level required for ATFM operations, conventional or long-range, will thus not be as stringent as what would otherwise be required for traffic sequencing tools.

Conceptual Considerations and Implementation Recommendations

5.2 Implementation Considerations (continued)

Data Exchange

Successful ATFM operations require good data exchange infrastructure between the ANSP and the stakeholders. Conventionally, the focus was on ground-ground connections, e.g., between the ATFM unit and the airline operations center (AOC). With LRATFM, however, there will be a requirement for air-ground information exchange. For example, the CTO from the ATFM unit will need to be delivered to the flight deck while the aircraft is airborne and – in most cases – overflying the airspace serviced by a different ANSP. How such information can be delivered to the flight deck is one of the major questions facing LRATFM implementation.

LRATFM will also require data exchanges between ANSPs and stakeholders beyond the conventional coverage of "short-range" ATFM, i.e., instead of exchanging flight and ATFM data within national or regional ATFM networks, an ANSP (ATFM unit) may need to exchange data with ANSPs in another region since ATFM information needs to be delivered to flights that are overflying distant FIRs. Different ANSPs/ATFM networks in various regions may have different ATFM systems and different means of data communication. The implementation of LRATFM will thus need to take into account those differences and to ensure ATFM data are able to be consumed by various systems used by all stakeholders.

An important question for LRATFM implementation, therefore, is how to define LRATFM data provision requirements and exchange mechanisms in a well-defined, standardised manner that ensures various, globally distributed and manufactured ATM support systems are all able to use it as desired. Emerging data exchange technologies such as System-Wide Information Management (SWIM) networks may present the most viable solution, and thus should be pursued in the context of ATFM and LRATFM.

Enabling Technologies

Multiple data exchange technologies have been developed to support the future of air traffic management; some of which can be leveraged to enable LRATFM operations. One of the most notable is the System-Wide Information Management (SWIM) concept, which provides a globally standardised data exchange framework. Given the potential reach of the LRATFM concept, and the extended communication horizon it requires, SWIM-based technologies may be the most viable solution for trans-regional, air-ground ATFM communication. Developments have been underway by various regional ATFM groups to ensure ATFM data elements – such as CTOT – are supported by SWIM standards, as exemplified by the Asia/Pacific's Flight Information Exchange Model (FIXM) extension which had been developed for the purpose of supporting distributed ATFM and A-CDM operations in the region.

A number of ANSPs and implementation groups have also been developing the Trajectory Based Operations (TBO) concept and supporting infrastructure, which describes the evolution toward a "proactive" ATM operation through capabilities such as real-time, accurate trajectory updates and exchanges, trajectory negotiations, and an information-rich operating environment. These TBO capabilities are natural enablers and/or enhancements to the LRATFM concept and can be leveraged.

As ANSPs and/or implementation groups begin to explore LRATFM, it is important to stay informed and involved in the development of these enabling technologies. They are still in their technological infancy and real operational use cases from ANSPs and implementation groups will be invaluable in ensuring the technologies are appropriate and beneficial to the operations.

Conceptual Considerations and Implementation Recommendations

5.2 Implementation Considerations (continued)

Inherent Dynamicity and Decision Support Tools

It is worth noting that ATFM is not an exact science. It is subject to a wide variety of environmental and operational conditions, caused by the dynamic environment in which aircraft operate. There will always be inaccuracies in the system, particularly when a delay is assigned to an aircraft still many hours from its destination.

To mitigate this, ANSPs are advised to ensure the data which drives their decision-making is current and accurate. They should employ decision support tools that can provide accurate demand predictions in all phases of ATFM and use modeling capabilities to assess the most appropriate ATFM solution to be applied. Similarly, the team members involved in assigning ATFM and LRATFM delays should have the necessary experience and knowledge to effectively prescribe ATFM solutions.

5.3 Managing LRATFM Implementation Cost

Implementing LRATFM is an investment and will require considerable resources. While it is difficult to make definitive statements on the cost of LRATFM systems, this section provides an overview of key cost drivers and how they can be managed.

Requirements

The more complex the requirements, the more costly the final solution. Where possible, the *"keep it simple"* principle should apply, noting that a simple system is likely to deliver a large portion of the desired outcomes and most of the benefits. It is essential to engage with relevant stakeholders, especially the airspace users, early in the implementation process to understand the desired outcomes.

Existing Systems

Where possible, existing ATFM and/or AMAN systems should be modified to meet the LRATFM requirements. This may provide both a cost-effective solution as well as integration with other key flow management systems to provide the best overall outcome.

Cross-System Integration

Integration and interfaces between different ATM support systems can add complexity to the software design. Where possible, limit the integration to elements that are strictly required for a successful LRATFM process and use internationally standardised information exchange protocols to enable trans-boundary, cross-region exchanges and harmonisation.

User Interaction

Ultimately the airspace users are the primary beneficiaries of LRATFM and designing the right level of user interactivity for them is critical to delivering the benefits. This is especially true when LRATFM solutions are implemented in conjunction with conventional ATFM solutions such as a Ground Delay Programme. Consideration should therefore be given to provide users with similar functionalities as are currently used for the notification and management of CTOTs and CTOs.

Application of Long-Range ATFM Concept

This chapter discusses how the Long-Range ATFM Concept proposed in Chapter 4 can be applied to various regions with existing ATFM operations or with plans to implement ATFM.

6.1 Europe

Network Manager

Europe has central coordination of ATFM, established in 1995 as a response to the chronic delays plaguing European air traffic throughout the 1980s. In its Single European Sky legislation, the European Commission created the Network Manager (NM) function to optimise the European aviation network's performance. They nominated EUROCONTROL as its NM from July 2011. From the Network Manager Operations Centre (NMOC) in Brussels, it provides ATFM for 43 states, 40 ANSPs, approximately 70 enroute centres and 500 airports. The NMOC is supported by Flow Management Positions located at the enroute ATC centres.

Procedures and systems

The NM has direct responsibility in the entire ATFM area covering 43 states. Any flight crossing the ATFM area may be subjected to ATFM measures which are planned and implemented by a series of specialised teams. The short-term strategic and pre-tactical ATFM team studies the demand for the day of operation, compares it with the predicted available capacity and prepares a plan for the day of operations. By doing so, efficiency is optimised, and demand and capacity are balanced by organising resources more effectively to implement a wide range of appropriate ATFM measures. After a process of Collaborative Decision Making, the output is the ATFM Daily Plan (ADP) and it is published via the Network Operations Portal (NOP) for use by airspace users (AUs) and other stakeholders. The tactical ATFM team optimises the demand and capacity in real-time on the day of operations. This function is supported by a computerised ATFM system known as the Enhanced Tactical Flow Management System (ETFMS), which includes a computer assisted slot allocation system. For ATFM measures (referred to as "regulations" in Europe), the NM allocates ATFM departure slots by means of a CTOT to better distribute the demand and limit delays for flights crossing congested airspace or destined for congested airports.

SESAR solution: CTOT and TTA

In 2015 the Single European Sky ATM Research Programme (SESAR) studied the concepts of CTOT and Target Time of Arrival (TTA) and Target Time Over (TTO) for Europe. The desired outcome was to complement departure regulations, such as the CTOT, with the dissemination of locally generated target times over the hotspot (TTA linked to the destination airport and TTO linked to a particular waypoint). Each airport collaborates with terminal area control units to develop its own strategy to allocate the available landing capacity. Strategies are likely to consider the consistency of flight plans with seasonally allocated airport slots, arrival routes and runway allocations, or gate and connection management. This collaborative process contributes to a more coherent approach to demand regulation, which is expected to result in a reduced number of knock-on delays thereby benefitting passengers and AUs, as well as the network. The solution provides more flexibility to AUs allowing them to adjust their actual take-off time (within their CTOT and the departure airport constraints) and flight profile (with new flight performance) whilst maintaining the TTO/TTA.

In 2016, the NM started to provide the TTO/TTA related to the most penalised regulation as part of the Slot Allocation Message. The message is sent to ANSPs concerned by the flight and to AUs Flight Operations Centre, currently it is for information purposes only and is not enforced.

Application of Long-Range ATFM Concept

6.1 Europe (continued)

iStream and xStream demonstrations

iStream was the demonstration project related to the SESAR solution on CTO and TTA described in the previous paragraph. The project was a collaborative effort between SWISS Air, Zurich Airport and Switzerland's ANSP, skyguide. The goal was to streamline the early arrival of long-haul flights to Zurich to prevent holding and ATC-delay and provide flexibility to airspace users. On the day before operations, the pre-tactical arrival sequence and TTOs are provided to AUs based on the scheduled times of arrival. AUs are required to consider these TTOs over the standard arrival route entries in their flight plans. In the tactical phase, airspace users are asked to provide Estimated Times Over (ETO) of their long-haul flights already airborne by email, hence an updated arrival sequence and TTOs can be provided. Five hours before landing, skyguide distributes the updated TTOs to airspace users by email and the airspace users should communicate the updated times to the flights concerned.

The project showed a high participation rate and ran successfully with significant increases in flight efficiency as well as the ability to incorporate airspace users' preferences into the decision making. In late 2016, the iStream procedure was implemented in the Swiss AIP and became mandatory for all inbound flights to Zurich arriving between 06:00 and 07:00 hours local time.

As a follow-up, xStream, a very large demonstration coordinated by the SESAR, organised trials to improve Extended Arrival Management (E-AMAN) operations at busy airports such as Zurich in 2018. As part of the trial, some recommendations of the iStream project were addressed. The ETO received from airlines and the TTOs from the computed arrival sequences were now fed back to the NMOC system. As a result, the trials showed an improved arrival predictability for both long- and short-haul flights to Zurich.

EU Common Project One

In 2021 the European Commission published the Common Project One regulation supporting the implementation of the European ATM Master Plan. Within the Common Project One, there are six functions that have been targeted for implementation. The first of these is referred to as Network Collaborative Management. The target date for implementation of this functionality at larger European airports is 31 December 2023.

As a sub functionality of Network Collaborative Management, the collaborative Network Operations Portal (NOP) shall be the continuous data exchange between the Network Manager and operational stakeholders' systems to cover the entire trajectory lifecycle and to reflect priorities as required by the NMOC to ensure the optimisation of the network functioning. The implementation of a collaborative NOP focuses on the availability of shared operational planning and real-time data. TT management will be part of collaborative NOP and will be applied to selected flights to manage demand at the point of congestion rather than only at departure. During the flight planning phase, the NMOC calculates a TT for a flight entering a location where time-based ATFM measures were applied.

In the foreseen operation, the NMOC must provide TT to AUs Flight Operations Centers together with the corresponding departure slot. In turn, AUs must inform their crews of any calculated slot and corresponding TT.

Application of Long-Range ATFM Concept

6.1 Europe (continued)

LRATFM perspective

The European regional ATFM services provided by NMOC are close to the conceptual LRATFM solution. Currently, any flight entering or transiting the ATFM area may be subjected to ATFM measures, not only flights originating from or terminating at one of the 500 airports under the authority of the NMOC. This way the NMOC can balance demand and capacity with a significant time horizon. Current ATFM efforts are predominantly based on ground delay programmes which are implemented through CTOT assignments. The demonstrations and implementation in Zurich show the positive result of applying TTs to long-haul flights already airborne outside the ATFM area, using local systems and procedures. At this time, relevant experience could be gained on the feasible time horizon and the possible delay absorption with LRATFM.

EU regulations require ATFM area-wide application of TT in support of LRATFM beginning in 2024. This will require system support for TT computation and dissemination via the NOP to AUs and ANSPs. As a result of other ATM functionalities mandated by the same regulation, it is expected that the availability and accuracy of trajectory information for long-haul flights outside the ATFM area shall improve by 2027. TTs should preferably also reach upstream ANSPs, providing them full awareness on flight intentions. Collaboration agreements between NM and most adjacent ANSPs are in place and, together with upcoming SWIM technology, this should allow for adequate data exchange.

Once the improved support systems and data quality that will result from the EU regulations can be realised and have been implemented, the current local applications of LRATFM could be adopted as general procedures of LRATFM for use in the entire NMOC ATFM area. Local FMP or the NM could then apply ATFM regulations to congested airports or airspace that generate TTs and corresponding CTOTs for aircraft on the ground. For aircraft airborne, yet outside the NMOCs ATFM area, TTs at congested airports or airspace and corresponding TTs at fixes/waypoints that demark entry into the NMOCs ATFM area could be generated too. The amount of time-delay assigned to an airborne flight with the TTs should be tailored to what can be absorbed in the remaining flight time. In NMOCs relatively large ATFM area, LRATFM shows potential to be applied to all airborne flights with sufficient remaining flight time, whether they are yet inside or outside the ATFM area.

6.2 Asia-Pacific

Introduction

Prior to the COVID-19 pandemic, the Asia-Pacific (APAC) region was one of the fastest-growing aviation markets in the world with rapid and sustained increases in air traffic demand – especially *intra-regional* flights. The rising traffic demand led to periodically excessive pressure on ATM resources (e.g., airports and airspace sectors) in the region that had already been operating at or near maximum capacity.

The pressure on the ATM resources prompted several APAC ANSPs and industry partners, including CANSO and IATA, to initiate an effort to design a cross-border ATFM concept that adequately accommodated the region's operational and geopolitical environment. The effort resulted in the creation of a **Distributed Multi-Nodal ATFM Network** concept, a framework to implement *distributed* cross-border ATFM without reliance on a centralised ATFM unit for the region.

The unique distributed ATFM concept adopted in APAC, with its framework for scalable, transboundary, inter-agency ATFM collaboration, is a good foundation for the application of LRATFM. As LRATFM operations will undoubtedly require collaboration between ANSPs and stakeholders beyond the "conventional" reach of national – and even regional – ATFM, APAC's distributed ATFM concept is well-suited to be expanded to support such operations.

Application of Long-Range ATFM Concept

6.2 Asia-Pacific (continued)

The Distributed Multi-Nodal ATFM Network Concept

The Distributed Multi-Nodal ATFM Network concept is based on a network of ANSPs leading independent ATFM operations within their areas of responsibility and connected to other ANSPs and stakeholders through effective information sharing and collaborative decision-making mechanisms. This is achieved with 2 operational principles:

- *Common Operating Procedure* that guides how cross-border ATFM measures – such as a Calculated Take-Off Time (CTOT) distribution in a Ground Delay Programme (GDP) – are to be used within the network; and
- *Interconnected Information Sharing Framework* that establishes mechanism and protocols for efficient ATFM information exchange among stakeholders in the network, thereby allowing key information – such as CTOTs – to be delivered to the right place at the right time for effective compliance facilitation.

These operational principles allow an ANSP to independently implement ATFM measure to manage both domestic and international traffic into resources where demand is exceeding capacity within their area of responsibility, while other ANSPs and stakeholders in the network can effectively comply with the ATFM measure based on the common operating procedures. This concept therefore removes the requirement for a centralised ATFM unit providing the service for the entire region but retains ANSPs' independence in managing their own ATM resources, a concept suitable for APAC's geopolitical environment.

The concept has been validated operationally by the **Asia-Pacific Cross-Border Multi-Nodal ATFM Collaboration (AMNAC)**, a group of 11 ANSPs[2] and industry partners (Airservices Australia, CANSO, IATA) that came together to implement the concept in the region. The primary ATFM measure chosen for the concept validation and implementation is the GDP, with CTOT being delivered via e-mails, ANSP web portals, and the Aeronautical Fixed Telecommunication Network/Aeronautical Message Handling System (AFTN/AMHS) messages based on the *Asia/Pacific AFTN/AMHS-Based Interface Control Document for ATFM*[3].

Since this distributed ATFM concept does not rely on a single entity providing ATFM service for the region, it can potentially be expanded beyond the reach of a "conventional" ATFM measure such as GDP. Specifically, measures applied under the LRATFM concept such as the delivery of and compliance with the Calculated Time Over (CTO) can be managed using a similar set of bases as that of the Distributed Multi-Nodal ATFM Network concept discussed above.

[2] AEROTHAI, CAAS, Hong Kong CAD, CAAC ATMB, CATS, CAAM, AirNav Indonesia, CAAP, VATM, DCA Myanmar, Lao ANS.

[3] The document can be found electronically on ICAO Asia/Pacific Regional Office's website, and the standards used are adapted from EUROCONTROL's ATS Data Exchange Presentation (ADEXP) format. Main messages used are Slot Allocation Message (SAM), Slot Revision Message (SRM), and Slot Cancellation Message (SLC).

Application of Long-Range ATFM Concept

6.2 Asia-Pacific (continued)

Long-Range ATFM Operations in a Distributed ATFM Environment

At the core of the Distributed Multi-Nodal ATFM Network concept is the framework for an ATFM measure – such as a GDP – implemented by an ANSP to apply to flights coming from beyond that ANSP's area of ATS responsibility. For example, a GDP implemented by the Bangkok ATFM Unit in Thailand can apply to flights flying into Thailand's airspace from Hong Kong or Singapore, with Hong Kong and Singapore ATS units facilitating CTOT compliance on departure. Without the concept, and the underlying principles previously discussed, such flights from outside of Thailand would have had to be exempted from the ATFM measure.

The LRATFM Concept, especially one based on the use of a CTO to manage airborne inbound traffic, can be managed in a comparable way. Specifically, the CTO would be delivered to the flight while it is transiting an upstream FIR under the control of a different ANSP and the role of complying with the CTO falls on the ATS unit whose airspace over which the flight is transiting and/or the flight crew operating the flight. This is similar to the way in which the Distributed Multi-Nodal ATFM Network concept is being applied in APAC, albeit with airborne flights rather than with flights yet-to-be-departed.

The operational implementation of LRATFM, therefore, can be established on similar principale as the Distributed Multi-Nodal ATFM Network concept. Specifically:

- A Common Operating Procedure or guideline, developed among participating network members to ensure common practices of CTO delivery rule, compliance facilitation, and CTO management methods; and
- An agreed LRATFM information exchange framework established, applying communication methods that are available to all participating ANSPs and stakeholders. Consideration should be given to how the information such as a CTO can be delivered to an airborne aircraft, as that can pose additional challenges compared to ground-ground communication employed for "conventional" ATFM measures such as a GDP.

With the principles for LRATFM implementation in a distributed ATFM environment being similar to the principles underlying the Distributed Multi-Nodal ATFM Network concept, the existing ATFM infrastructure in APAC can be expanded to include more ANSPs in the region. Because of the size of the region, some intra-regional flights are already beyond the reach of a conventional GDP. For example, the 6-/7-hour flights from Japan and Republic of Korea are usually exempted from GDPs implemented by Bangkok and Singapore ATFM Units as the aircraft are generally airborne by the time a programme is activated. With the LRATFM applied in the region, such flights could now be included – with CTOs assigned – along with other CTOT-controlled flights from nearer departure points.

The adoption of LRATFM in APAC would allow the existing distributed ATFM network to be expanded to include flights from the west (in India and Pakistan), from the north (in Japan and Republic of Korea), and from the south/southeast (in Australia and New Zealand). These flights can be managed using a LRATFM measure such as CTO in an integrated manner with other short and medium-haul flights in the region.

There will be challenges in expanding the APAC network to connect to other regions with established or developing ATFM operations such as the Middle East and Europe, as both sides' ATFM infrastructure and procedures may need to be adjusted for seamless trans-regional operations. For this reason, a networked LRATFM concept should remain the same, with commonly agreed principles and procedures and common information exchange framework established through transboundary collaboration.

Application of Long-Range ATFM Concept

6.2 Asia-Pacific (continued)

The Way Forward for Long-Range ATFM Exploration in APAC

In APAC, some ANSPs have started LRATFM exploration. Specifically:

- *CAAS (Singapore), Airways (New Zealand), and NATS (UK)* conducted an operational research project to trial the LRATFM concept by assigning Target Time Over (TTO) a specific metering waypoint to long-haul inbound aircraft to manage the arrival demand. The project, commenced in 2017, tested the communication process, time estimate accuracy, and flight crew's interactions and compliance with the ATFM requirement in operations. The project also identified the appropriate amount of ATFM time delays that could be realistically absorbed by flights enroute (~1-3 minutes per each remaining flight hour), which can be used as a guideline for ANSPs when considering the use of TTO/CTO as an LRATFM measure.
- *Airservices Australia* also began conducting operational research into extending their ATFM operations to include long-haul arrivals by providing Calculated Time Over (CTO) an arrival waypoint to flights with approximately 4 hours left before arrival. The project aimed at integrating these long-haul (international) arrivals into their existing short-haul domestic ATFM operation, thereby distributing required ATFM delays more equitably and ensuring long-haul flights can absorb delays more efficiently in the cruise phase of flight. Given the size of the Australian administered airspace, it is worth noting that *Airservices* was able to assign CTOs to flights while they were already in the Australian airspace, which significantly reduced the complexity that would otherwise arise were the LRATFM requirement needed to be delivered and managed by an upstream ANSP.

These initiatives speak to the needs of some ANSPs in the region to include long-range inbound traffic as part of their ATFM operations to distribute ATFM delays more equitably among airspace users and to improve the effectiveness of an ATFM programme.

Several other APAC ANSPs have also expressed interest in joining the regional ATFM network; some have commenced ATFM operational trials with AMNAC core members. For examples:

- *AAI (India)* has shown interest in expanding the scope of their ATFM operations beyond domestic flights, and in supporting the ATFM measures implemented by their counterparts in East and Southeast Asia. From the perspective of "further east" ANSPs such as Hong Kong CAD and Airservices Australia, flights from the Indian airspace can be considered medium- or long-range flights and AAI's participation in the APAC ATFM network will enable the use of LRATFM measures with them.
- *KOCA (Korea), JANS (Japan), and ANWS (Chinese Taipei)* have closely followed the development of AMNAC over the years and have begun GDP operational trial with Hong Kong CAD. Flights from Incheon, Fukuoka, and Taipei FIRs are usually considered medium- or long-range flights from the perspectives of "further south" ANSPs such as AEROTHAI (Thailand) and CAAS (Singapore) as they are usually airborne by the time GDPs are activated in Thailand and/or Singapore. With KOCA, JANS, and ANWS – and their local stakeholders – becoming familiar with the region's distributed ATFM operations, the adoption of LRATFM under a similar principle should be feasible.

Application of Long-Range ATFM Concept

6.2 Asia-Pacific (continued)

The Way Forward for Long-Range ATFM Exploration in APAC (continued)

With these additional ANSPs' participation in the regional ATFM network, the APAC region can begin to explore the integration of LRATFM concept based on CTO assignment with the existing distributed GDP operations based on CTOT; and airborne flights can be seamlessly managed alongside their shorter-range counterparts within the region.

The expansion of the ATFM network to cover the entire APAC region can then be a basis for further collaboration with counterparts in the Middle East and Europe to pave the way for seamless trans-regional flight operations with both "conventional" ATFM and LRATFM as the foundation for well-balanced demand and capacity, and for safe and efficient air traffic service provision.

6.3 The United States of America, Latin America and the Caribbean

For the Federal Aviation Administration (FAA) in the United States of America, the Traffic Management System's mission is to balance air traffic demand with system capacity to ensure the maximum efficient utilisation of the National Airspace System (NAS). A safe, orderly, and expeditious flow of traffic while minimising delays is fostered through continued analysis, coordination, and dynamic utilisation of traffic management initiatives and programmes. The Air Traffic Control System Command Center (ATCSCC) monitors and manages the overall flow of air traffic throughout the NAS. Each of the 20 Air Route Traffic Control Centers (ARTCC) in the conterminous United States and the large Terminal Radar Approach Control (TRACON) centers all have a Traffic Management Unit (TMU) that monitors and balances traffic flows within its area of responsibility in accordance with traffic management directives. The ATCSCC provides the overall guidance and direction for national traffic management initiatives and works collaboratively with the airspace users, airport operators and TMUs to facilitate the safe, orderly, and expeditious flow of traffic throughout the NAS.

More than 80% of the daily traffic in the NAS are domestic flights operating within the conterminous United States. Most traffic management initiatives or measures are only applied to domestic flight operations. The exception is flights to and from Canada that can be included in US and Canadian traffic management initiatives. International flights are not subject to traffic management initiatives at the point of departure but are accounted for in the traffic management system for any initiatives that may be implemented along their route of flight while operating in the NAS. While the FAA does not have any direct examples of Long Range ATFM currently utilised in the NAS, there are a couple of examples which may further the discussion of the concept.

Application of Long-Range ATFM Concept

6.3 The United States of America, Latin America and the Caribbean (continued)

Structured routing to facilitate MIT for JFK airport

John F. Kennedy Airport (JFK) in New York City currently has schedule demand and ongoing construction impacts that continue to create a constraint for the first arrival period in the morning (which are mostly overnight flights from the west coast of the USA). The demand and associated runway construction has created a constraint for N90 (New York TRACON). N90 utilises a 10 minutes-in-trail (MIT) Traffic Management Initiative (TMI) on the arrival fix LENDY to manage the traffic arriving from the west. The MIT is passed back from sector to sector creating the need for route structure for Cleveland ARTCC (ZOB) to be able to effectively manage and blend the traffic flows and meet the MIT restriction. The ATCSCC will coordinate specific routes for JFK using a Flow Constrained Area (FCAMID) with all facilities prior to the 0115 UTC strategic planning teleconference. The discussion will evaluate any expected enroute impacts that would require adjustment to the routes. All flights arriving JFK during the timeframe established for the constraint will be required to file and fly these specific routes. These routes establish the JFK arrivals on a structured flow of traffic and increases the ability of ZOB to manage the MIT restriction with the least impact to both the controller and pilot workload.

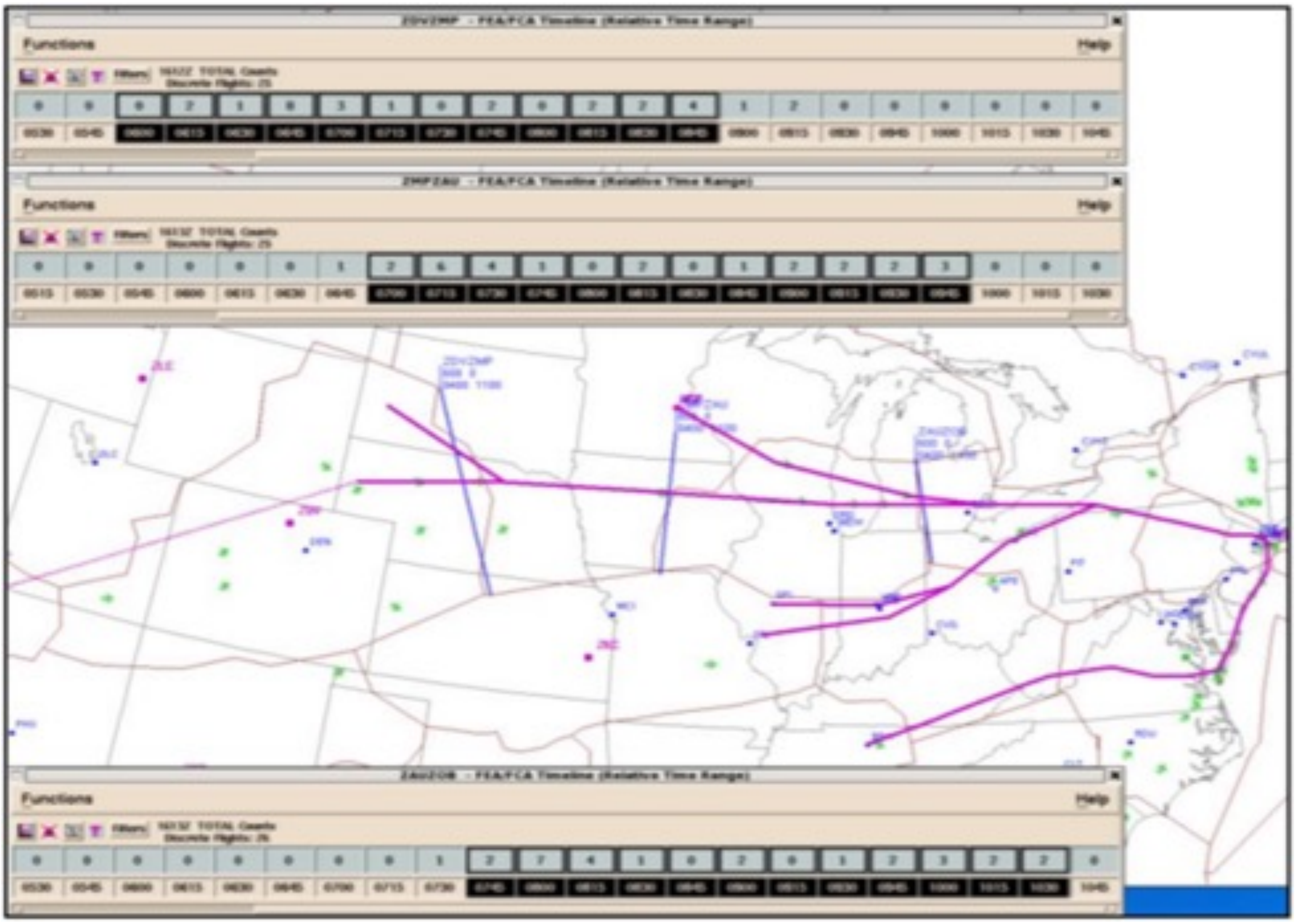
Origin	Destination	Route
MSP	JFK	MSP>DLL HASTE DAFLU J70 LVZ<LENDY6
ZSE	JFK	>RAP ONL FOD KG75M DAFLU J70 LVZ<LENDY6
ZDV ZOA ZLC LAS	JFK	>BFF ONL FOD KG75M DAFLU J70 LVZ<LENDY6
ZLA ZAB ZKC -LAS	JFK	>SPI VHP ROD DJB JHW J70 LVZ<LENDY6
ZLA ZAB ZKC -LAS	JFK	>KK54K KI570 ROD DJB JHW J70 LVZ<LENDY6
ZFW ZHU ZME	JFK	>BKW J42 MOL J24 HCM SAWED J121 SIE<CAMRN4

ZID can offload internal departures on the BKW route.

Application of Long-Range ATFM Concept

6.3 The United States of America, Latin America and the Caribbean (continued)

Structured routing to facilitate MIT for JFK airport (continued)



The ATCSCC will enter the NTML (National Traffic Management Log) restriction to keep JFK flights on assigned routes during the constrained period. The NTML Route Restriction for Minneapolis ARTCC, Kansas City ARTCC, Denver ARTCC, Salt Lake City ARTCC, Albuquerque ARTCC, Los Angeles ARTCC, Oakland ARTCC and Seattle ARTCC will leave all JFK arrivals on the assigned required route. Any change in route from published advisory route requires approval from ATCSCC. If a flight is moved from assigned route for safety reasons, the flight is returned to the assigned route as soon as possible.

Once the routes are published, generally within 10 minutes, the MIT restrictions are implemented, and coordination is accomplished via the NTML with all the affected facilities. This is all accomplished at the beginning of the Midnight Shift prior to flights departing the West Coast. The ATCSCC will monitor and evaluate the demand for adjustments in the MIT. The ATCSCC will also monitor for route conformance and coordinate with the ARTCCs for any route adjustments.

Application of Long-Range ATFM Concept

6.3 The United States of America, Latin America and the Caribbean (continued)

Trajectory Based Operations

Trajectory-Based Operations (TBO) is an ATM method for strategically planning and managing flights throughout the NAS by using Time-Based Management (TBM), information exchanged between air and ground systems, and the aircraft's ability to fly trajectories in time and space. Aircraft trajectory is defined in four dimensions—latitude, longitude, altitude, and time. While TBO is still in development, it will increase airspace and airport throughput, flight efficiency, flexibility, and predictability through TBM, Performance Based Navigation (PBN) procedures, and increased collaboration with airspace users regarding preferred trajectories and priorities. TBM operations include, but are not limited to, arrival metering, surface metering, terminal metering, and departure scheduling. TBO initially will focus on domestic NAS operations, but it is envisioned to potentially be expanded to include LRATFM initiatives.

TBO objectives must be prioritised when developing and executing the traffic management mission. TBO objectives include continuous and collaborative strategic planning, use of TBM, and use of PBN procedures when possible. TBM is a methodology for managing the flow of air traffic through the assignment of crossing times at specific points along an aircraft's trajectory. TBM applies time to mitigate demand/capacity imbalances while enhancing efficiency and predictability of the NAS. TBM techniques and tools will be used even during periods when demand does not exceed capacity. This sustains operational predictability and regional/national strategic plans. TBM utilises capabilities within the traffic flow management system designed to achieve a specified interval between aircraft.

The efficiency of the NAS is enhanced when all participants have access to the same data. Utilisation of shared technology, e.g., TBO data, trajectory options set (TOS), surface data, Flow Constrained Area (FCA)/ Flow Evaluation Area (FEA) enhances the coordination process and is critical to the success of trajectory-based operations. The ATCSCC is the approval authority for all inter-facility TBM operations. While each facility retains authority for the implementation of TBM operations in its airspace, the ATCSCC will be the final authority on how those operations are carried out and the priorities they are assigned in order to best support the objectives and overall efficiency of the NAS.

Latin America and Caribbean CADENA ATFM

CADENA – the CANSO ATFM Data Exchange Network for the Americas – is an initiative to promote and facilitate the safe and efficient movement of air traffic in the Latin America and Caribbean (LAC) region through effective implementation of air traffic flow management (ATFM) and collaborative decision-making (CDM). In the operational context of CADENA, representatives from Air Navigation Service Providers (ANSPs), airspace users, airports, military, and international organisations (e.g., ICAO, IATA, ALTA, ACI) work together to develop and implement procedural and technological solutions to solve the complex ATFM challenges faced by the LAC airspace system. CADENA is a harmonised approach that allows ANSPs and stakeholders to meet regularly, learn from each other, share operational information and operating preferences, build a common understanding, establish procedures, develop tools, and thus achieve greater aviation system efficiency.

To share operational information, CADENA uses web conference technology and has developed the CADENA Operational Information System (CADENA OIS) web platform. Daily, participating CADENA ANSPs utilise the CADENA OIS to input their ATFM Daily Plans to make the stakeholders aware of their current operational situation.

Application of Long-Range ATFM Concept

6.3 The United States of America, Latin America and the Caribbean (continued)

Latin America and Caribbean CADENA ATFM (continued)

Every week, CADENA hosts the CADENA Planning Web Conference which allows stakeholders from the LAC Region to meet via webinar, discuss the operational outlook for each weekend, discuss potential ATFM measures, and develop a collaborative Regional Operations Plan. And when the need arises, CADENA schedules and hosts CDM web conferences on an ad-hoc basis to address significant operational constraints in the LAC airspace system. These ad-hoc web conferences are convened at stakeholder or ANSP requests to address topics such as the impact of tropical storms, volcanic ash, work stoppages, staffing shortages, etc.

During significant events such as a complete outage of an Area Control Centre (ACC) or the impact of a major hurricane, CADENA has developed, in collaboration between the airspace users and participating ANSPs, the Planned Airway System Alternatives (PASA) contingency routes that can be used to temporarily route around the impacted airspace. The PASA route database is based on routes that are already in use by the airspace users and have been approved by the participating ANSPs. The route database is reviewed and updated on a quarterly basis and is available on the CADENA OIS under the "Information" tab on the CADENA OIS homepage and then under "Reroute Repository." When an event occurs that requires implementation of the PASA contingency routes, CADENA will schedule and convene an ad-hoc Web Conference to coordinate the use of specific routes. The host for the ad-hoc Web Conference will depend on which ANSP is impacted and which Flow Management Unit is available to serve as host.

The host will facilitate the collaborative discussion and ensure the following points are covered:

- Review the known details regarding the event that led to application of the routes.
- Discuss which routes may and will be used to circumnavigate the impacted airspace(s).
- Ensure the receiving ANSPs can support the routes.
- Ensure the airlines and other airspace users have adequate time to plan and fuel for the routes. Normally, a three-to-four-hour lead-time planning window is preferred.
- Determine how long the routes will be in effect.
- Determine, to the extent possible, the demand on the routes in an appropriate time segment (such as per 15 minutes, or per hour).
- Establish, if necessary, ATFM measures to manage the demand.
- Determine the strategy for exiting the routes and returning to normal operations when the event ends.

The PASA routes create an efficient flow of traffic during significant disruptions to the system and allow both the ANSPs and airspace users to predictably manage unusual situations to the benefit of all stakeholders.

Each of these three examples – JFK wind routes, Trajectory Based Operations, and CADENA – demonstrate a collaborative approach with all stakeholders to improve the efficiency and predictability of the aviation system. These initiatives have proven beneficial to the overall management of the NAS within the United States and for the Caribbean, Latin American and South American regions. Through collaboration with all stakeholders, these processes have been established to address normal day-to-day operations as well as significant disruptions to the airspace. Efforts like CADENA demonstrate a regional approach to addressing constraints involving multiple ANSPs who work together to provide flight operators as well as other stakeholders with the information necessary to manage their operation and improve traffic flow management throughout the Americas.

Application of Long-Range ATFM Concept

6.4 Middle-East

No known LRATFM study has been undertaken in the MIDEAST region. The airspace and aerodromes in the region have become progressively busier over the past years. ANSPs in the region are not only dealing with significant growth at the hub airports but also growth in traffic transiting the airspace. This is exacerbated by political conflicts in the region requiring traffic to be routed into already busy airspace. The region has accepted the Distributed Multi-Nodal ATFM Network concept of operations as the model for ATFM in the region. While there are regional flights which could participate in traditional ATFM measures, most flights are long-range flights requiring LRATFM solutions.

ATFM implementation within the region is in the preliminary stages of development. From the surrounding FIR though, EUROCONTROL, India and the AMNAC ATFM groupings are all represented on the various ICAO ATFM implementation task forces in the Middle East. ATFM in the region then receives some benefit and peripheral flow management from the ATFM activities of these neighboring ANSPs. While no arrangement currently exists to include flights in ATFM measures regionally, it is accepted that, for ATFM to be effective in the Middle East region, LRATFM will need to be implemented.

The model of ATFM as proposed in Chapter 4 of this document could be implemented in the Middle East region. Domestic and regional traffic would be subject to ATFM measures such as a GDP, where they would be issued with a CTOT. Should an ATFM measure be implemented after flights are airborne from aerodromes outside of the Middle East region, a CTO will be calculated for a waypoint in the airspace where the flight will be required to cross that waypoint as close as possible to the CTO. As traffic coming from the east and the west have come from or have departed from areas where ATFM is already implemented, the passing and reception of CTOs is expected to be easily understood and information easily distributed to relevant ANSPs and airspace users. It will be accepted that traffic departing or transiting the Middle East airspace could be subject to LRATFM measures in implemented in the European, Indian and APAC airspace. In preliminary stages of LRATFM, the CTOs could be passed through e-mail, AFTN/AMHS (Slot Allocation Messages), or interactive web platform. As the process matures, electronic connectivity between systems will be required for automatic exchange of ATFM messaging. CTO transmission to airspace users can also be done by methods as described above. There is some advantage gained in the region where a substantial proportion of the traffic from some countries are predominantly the same airline, enabling simpler distribution of ATFM messages.

Application of Long-Range ATFM Concept

6.5 Africa

No known LRATFM is being practiced in Africa. ATFM implementation in Africa is in a developing phase with some ATFM being implemented. South Africa implemented ATFM in 2010 and ATNS – the ANSP for the country – continues to conduct ATFM operations daily, albeit including only domestic traffic. Some North African countries are participating in the ATFM processes with the EUROCONTROL Network Manager.

CANSO is attempting to facilitate ATFM implementation in Africa through the *Mombasa ATFM Roadmap*[4]. There are plans for ATNS to include regional traffic in their ATFM measures, however, this would not necessarily require LRATFM. There are some regions where regional ATFM could be an effective way to perform ATFM. ATFM in these regions could include LRATFM.

In the future, as EUROCONTROL Network Manager, India, and the Middle East implement and/or expand their ATFM scope of operations, flights to those areas from Africa may also be subject to LRATFM measures.

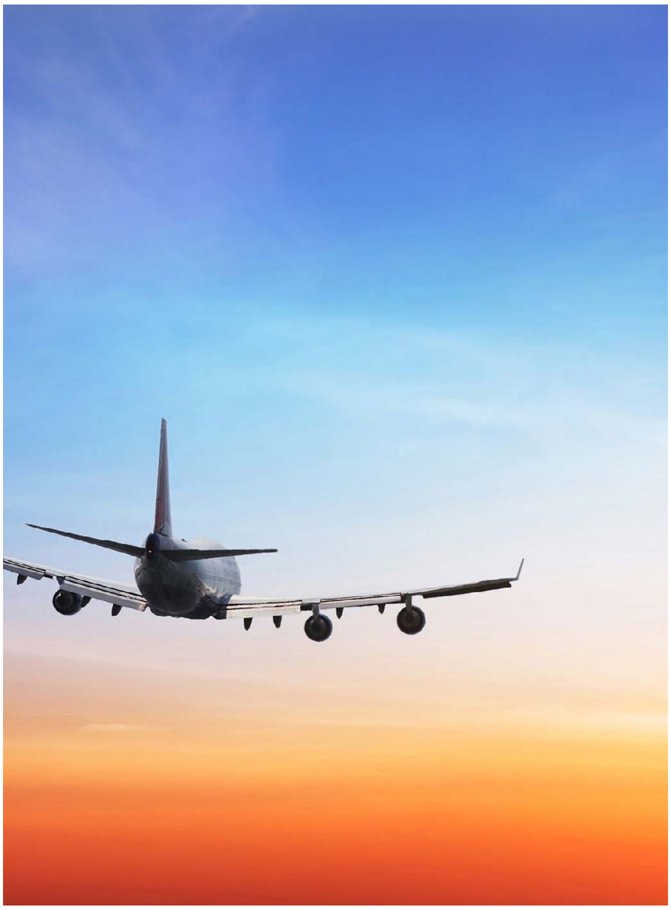
The model of ATFM as proposed in Chapter 4 of this document may eventually be implemented in the African region. Domestic and regional traffic would be subject to ATFM measures such as a GDP where they would be issued with a CTOT. Should an ATFM measure be implemented after flights are airborne, a CTO can be calculated for a waypoint in the airspace where the flight will be required to cross that waypoint as close as possible to the CTO. In preliminary stages of LRATFM, the CTOs could be passed through e-mail, AFTN/AMHS (Slot Allocation Messages), or interactive web platforms. As the process matures, electronic connectivity between systems will be required for automatic exchanges of ATFM messaging. CTO transmission to airspace users can also be done by methods as described above.

[4] Information on the Mombasa ATFM Roadmap can be found at https://canso.org/our-regions/africa/canso-mombasa-atfm-roadmap/

Research Areas

This chapter discusses ongoing academic research into areas of possible improvements to the Long-Range ATFM concept, including airborne delay absorption, trajectory prediction, and enhanced AMAN/DMAN systems.

The LRATFM concept and trials discussed in previous chapters focused on the extension of current ATFM measures to integrate long-haul flights, thereby providing a more equitable allocation of delays and increasing accuracy and predictability for the flights. Areas of academic research into ATFM optimisation that support the development of the current LRATFM concepts include the previously discussed GDP optimisation and equitable delay allocation through CDM processes. Additional areas of study that may enhance the current LRATFM concept include a developed understanding of achievable delay absorption through speed adjustments, aircraft trajectory prediction accuracy, and enhanced Arrival Management (AMAN) and Departure Management (DMAN) systems. This chapter discusses some of ongoing research that can be the basis for further enhancements of the LRATFM concept.



7.1 Achievable Delay Absorption through Speed Adjustments

An understanding of achievable delay absorption through speed adjustment without significantly impacting fuel consumption is crucial to the enhancement and feasibility of the LRATFM concept. Linear holding describes the application of speed adjustments to incur delays in the cruise phase of flight and is aimed at partially absorbing initially assigned ground delays by flying at reduced speed within planned fuel consumption (Xu & Prats, 2017). Xu & Prats (2017) proposed a strategy to include linear holding into ATFM measures through utilising the maximum linear holding for an optimal aircraft trajectory. Xu & Prats (2017) identified that incorporating linear holding as an additional ATFM measure provides flexibility and allows for the optimal distribution of delay across the network. Irvine (2015) identified that, on average, short -haul flights were only able to make relatively small corrections through speed adjustments, so the application may be better in long range scenarios.

As previously explored, the CAAS and Airways' CTO trials identified that in their operational environments achievable delay absorption was between 1-3 minutes per flight hour. Matsuno & Andreeva-Mori (2020) analysed the achievable airborne delay and compliance rate by speed control through simulations on international arrivals at Tokyo-Narita International Airport. The simulation results indicated that 2-4 minutes in delays per 30-minute flight time was achievable on average with high compliance rates. An additional 2-3% fuel savings can also potentially be expected from the speed reduction despite the flight time increase (Matsuno & Andreeva-Mori, 2020). The difference between operational trial data and the latest academic research brings to light the need for a more detailed understanding of maximum linear holding for flight trajectories and how that can be implemented into an LRATFM concept to support the effective distribution of delay.

Research Areas

7.2 Increased Accuracy of Trajectory Predictions

The accuracy of trajectory predictions in enroute airspace can impact the predictability of estimated time over (ETO) control waypoints, which is a key element to the LRATFM concept (Park & Park, 2011). Rosenow, Fricke, Luchkove & Schultz (2019) identify that the use of optimised trajectories in ATFM lead to more evenly distributed airspace capacity as well as reductions in fuel burn, ATC charges, and environmental impacts. Inaccurate trajectory predictions can lead to less-than-optimal tactical ATFM measure applications, incur higher costs to airspace users, and increase ATC workload (Park & Park, 2011 and Rosenow et al., 2019).

Mondoloni & Rozen (2020) discuss the importance of trajectory prediction in ATM, particularly for ATFM automation and AMAN. Flight trajectories form the basis for an estimate of the expected demand loading on the capacity of resources, and errors in trajectory prediction can lead to the loss of capacity and ATM operational efficiency. The capacity and efficiency loss can then cause unwanted delays through the network (Mondoloni & Rozen, 2020). Trajectory Based Operations (TBO) is identified by the industry and academic resources as a solution to the current ATFM limitations. TBO seeks to improve information sharing and coordination through the provision and integration of shared information over System-Wide Information Management (SWIM) technologies (Mondoloni & Rozen, and Kisten et al). The development of TBO and associated 4-dimentional trajectory optimisation represents an evolutionary change in ATM. The accuracy and reliability of data expected to be provided in the TBO environment can be the missing link to dynamic LRATFM concepts (Kistan et al.).

7.3 Arrival Management (AMAN) and Departure Management (DMAN)

AMAN is a crucial aspect to facilitating the smooth flow of aircraft into airports. According to Kistan et al (2016) AMAN efficiency is maximised when integrated with a Departure Management (DMAN) tool, allowing slot allocation to be extended to encompass departures. A DMAN tool aims to support the pre departure planning processes and is primarily introduced at airports when A-CDM is implemented (Jonge, Tuinstra & Seljee). DMAN automatically computes and monitors the required spacing for departing flights and determines the optimal sequence for departures from multiple runway configurations. The goal of DMAN is to prevent excessive departure queuing and to help reduce fuel consumption (Kistan et al).

The integrated AMAN/DMAN sequencing concept aims to leverage trajectory prediction using FMS data, aircraft-derived data for intent, and performance data (Kistan et al.). Integrated AMAN/DMAN seeks to reduce delays and to maximise runway capacity utilization through the optimisation of arrival and departure flows. Integrated AMAN/DMAN can support cross border ATFM for closely spaced airports, allowing for coordination of departures at one airport with arrivals at the other. Information sharing and enhanced trajectory prediction enabled by SWIM could then be fed into the integrated AMAN/DMAN system to ensure flights are not unnecessarily penalised by multiple ATFM measures (Kistan et al.)

The academic literature surrounding ATFM optimisation points to the dynamic nature of ATM and the importance of predictability of air traffic operations to ensure that the demand and capacity can be monitored and managed. The efficient and accurate sharing of information is crucial to facilitate the safe and efficient flow of traffic. From a LRATFM's perspective, the key areas of development all interrelate; increased accuracy of trajectory predictions can support efficient CTO fix assignment with achievable airborne delay compliance by airspace users. As operations become optimised through increased predictability, the integration of AMAN and DMAN systems can ensure that the smooth flow of traffic achieved prior to airports is maintained.

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Appendix A: High-Level Long-Range ATFM Use Case

This appendix contains a high-level use case describing an example process for utilising LRATFM (CTO) and ATFM (GDP) solutions to manage a stream of short- and long-haul aircraft to a constrained ATM resource.

Introduction

The following series of tables illustrate the application of the LRAFTM concept on a set of sample flights comprising both airborne and on-ground aircraft that are flying or are planned to fly to an airport that is capacity constrained.

Operating Environment

A series of aircraft are flying or planned to fly to a constrained airport.

Arriving aircraft demand is managed by GDP programme and traffic synchronisation is managed within 200nm through an arrival management system which sequences aircraft to land through Feeder Fixes (FF) at approximately 40NM from touchdown. The LRATFM meters aircraft outside the AMAN horizon by issuing CTO for Outer Fixes (OF) at 200NM from the airfield or CTOT times to aircraft which are yet to depart.

An aircraft's landing sequence is determined by its Estimated Landing Time (ELDT) which is derived from the ETA for the OF (ETA_OF) and the ETA for the FF (ETA_FF).

The maximum time an aircraft can lose in flight is the MaxDLA and is calculated by allowing two minutes for each hour that an aircraft has to fly to the OF (TT_OF). Therefore MaxDLA=2(TT_OF).

Aircraft subject to a GDP are issued a Calculated Take Off Time (CTOT).

Aircraft subject to airborne delay by LRATFM are issued a Calculated Time Over (CTO).

Appendix A: High-Level Long-Range ATFM Use Case

Step-by-Step Workflow

Step 1 - Calculate Initial landing sequence order (ELDT) where the FF is at 40NM and the OF is at 200NM

In this step, the aircraft are listed in order of arrival at the Destination (ADES) using the ELDT. The initial Calculated Landing Time (CLDT) is then determined by adding the required spacing between arrivals.

Status	Aircraft	ELDT	CLDT	ETA_FF	ETA_OF	DLA RQD	CTOT	CTO	Time GDP Run	TT_OF	MaxDLA	Notes
LRATFM eligible	FLT01	4:07	4:33	3:53	3:32							
GDP eligible	FLT02	4:07	4:30	3:53	3:32							
LRATFM eligible	FLT03	4:06	4:27	3:52	3:31							
GDP eligible	FLT04	4:05	4:24	3:51	3:30							
GDP eligible	FLT05	4:04	4:21	3:50	3:29							
GDP eligible	FLT06	4:04	4:18	3:50	3:29							
LRATFM eligible	FLT07	4:03	4:15	3:49	3:28							
GDP eligible	FLT08	4:01	4:12	3:47	3:26							
GDP eligible	FLT09	4:01	4:09	3:47	3:26							
GDP eligible	FLT010	4:01	4:06	3:47	3:26							
LRATFM eligible	FLT011	4:00	4:03	3:46	3:25							
GDP eligible	FLT012	4:00	4:00	3:46	3:25							

Appendix A: High-Level Long-Range ATFM Use Case

Step-by-Step Workflow

Step 2 - Calculate Initial landing sequence order (CLDT)

In this step, the final CLDT is calculated by identifying the MaxDLA and assigning that to airborne aircraft (LRATFM eligible).

Status	Aircraft	ELDT	CLDT	ETA_FF	ETA_OF	DLA RQD	CTOT	CTO	Time GDP Run	TT_OF	MaxDLA	Notes
LRATFM eligible	FLT01	4:07	4:33	3:53	3:32	0:26		4:14	0:00	3:32	0:07	unable to achieve initial
GDP eligible	FLT02	4:07	4:30	3:53	3:32	0:23			0:00	3:32	0:07	
LRATFM eligible	FLT03	4:06	4:27	3:52	3:31	0:21		4:13	0:00	3:31	0:07	unable to achieve initial
GDP eligible	FLT04	4:05	4:24	3:51	3:30	0:19			0:00	3:30	0:07	
GDP eligible	FLT05	4:04	4:21	3:50	3:29	0:17			0:00	3:29	0:07	
GDP eligible	FLT06	4:04	4:18	3:50	3:29	0:14			0:00	3:29	0:07	
LRATFM eligible	FLT07	4:03	4:15	3:49	3:28	0:12		4:10	0:00	3:28	0:07	unable to achieve initial
GDP eligible	FLT08	4:01	4:12	3:47	3:26	0:11			0:00	3:26	0:07	
GDP eligible	FLT09	4:01	4:09	3:47	3:26	0:08			0:00	3:26	0:07	
GDP eligible	FLT010	4:01	4:06	3:47	3:26	0:05	Issued		0:00	3:26	0:07	
LRATFM eligible	FLT011	4:00	4:03	3:46	3:25	0:03		3:28	0:00	3:25	0:07	can achieve the LRATFM delay
GDP eligible	FLT012	4:00	4:00	3:46	3:25	0:00	Issued		0:00	3:25	0:07	

Appendix A: High-Level Long-Range ATFM Use Case

Step-by-Step Workflow

Step 3 - Calculate final landing sequence order (CLDT) by giving no more than the time able to be lost (MaxDLA) to LRATFM eligible

In this step, the landing sequence is re-ordered, based on the ability of aircraft to achieve the required delay.

Status	Aircraft	ELDT	CLDT	ETA_FF	ETA_OF	DLA RQD	CTOT	CTO	Time GDP Run	TT_OF	MaxDLA	Notes
GDP eligible	FLT02	4:07	4:33	3:53	3:32	0:26	Issued		0:00	3:32	0:07	
GDP eligible	FLT04	4:05	4:30	3:51	3:30	0:25	Issued		0:00	3:30	0:07	
GDP eligible	FLT05	4:04	4:27	3:50	3:29	0:23	Issued		0:00	3:29	0:07	
GDP eligible	FLT06	4:04	4:24	3:50	3:29	0:20	Issued		0:00	3:29	0:07	
GDP eligible	FLT08	4:01	4:21	3:47	3:26	0:20	Issued		0:00	3:26	0:07	
GDP eligible	FLT09	4:01	4:18	3:47	3:26	0:17	Issued		0:00	3:26	0:07	
LRATFM eligible	FLT01	4:07	4:15	3:53	3:32	0:08		3:40	0:00	3:32	0:07	Max LRATFM assigned
LRATFM eligible	FLT03	4:06	4:12	3:52	3:31	0:06		3:37	0:00	3:31	0:07	Max LRATFM assigned
LRATFM eligible	FLT07	4:03	4:09	3:49	3:28	0:06		3:34	0:00	3:28	0:07	Max LRATFM assigned
GDP eligible	FLT010	4:01	4:06	3:47	3:26	0:05	Issued					
LRATFM eligible	FLT011	4:00	4:03	3:46	3:25	0:03		3:28	0:00	3:25	0:07	can achieve the LRATFM delay
GDP eligible	FLT012	4:00	4:00	3:46	3:25	0:00	Issued		0:00	3:25	0:07	

Step 4 - CTO and CTOT are passed to aircraft

Step 5 - As aircraft leave the LRATFM arena and enter the AMAN/XMAN arena, tactical traffic sequencing advice is issued by the AMAN/XMAN system based on their order of presentation into the arena. Aircraft are streamed into the destination airport

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